COMBUSTION

DEVOTED TO THE ADVANCEMENT OF STEAM PLANT DESIGN AND OPERATION

March 1959

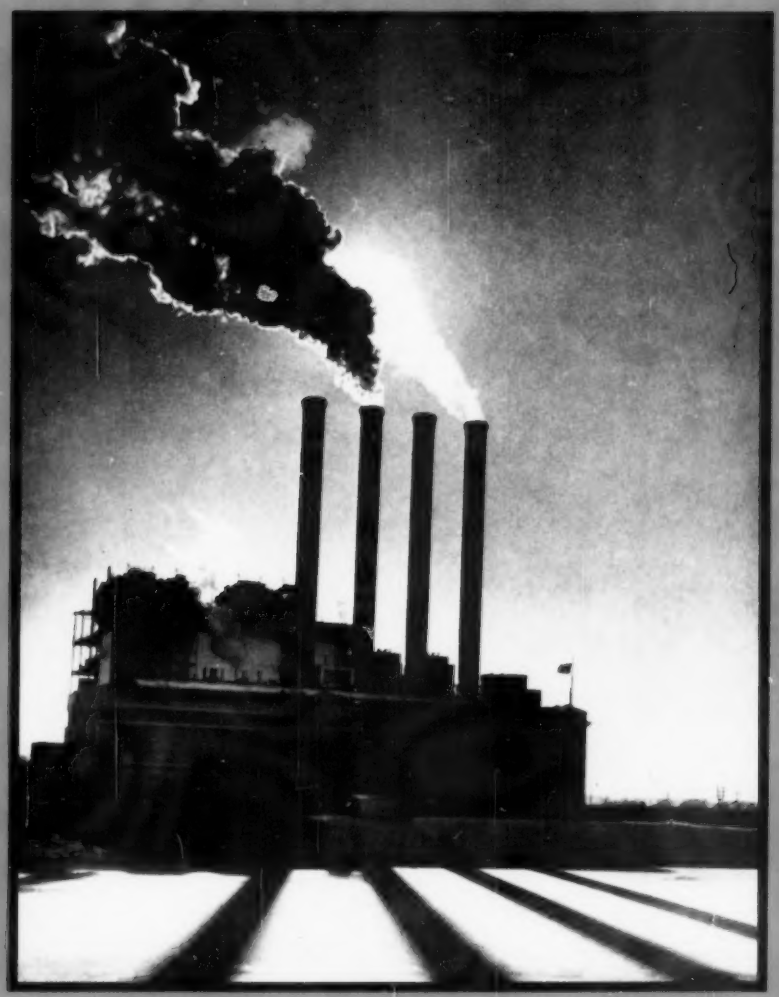


Photo by Bob Doty

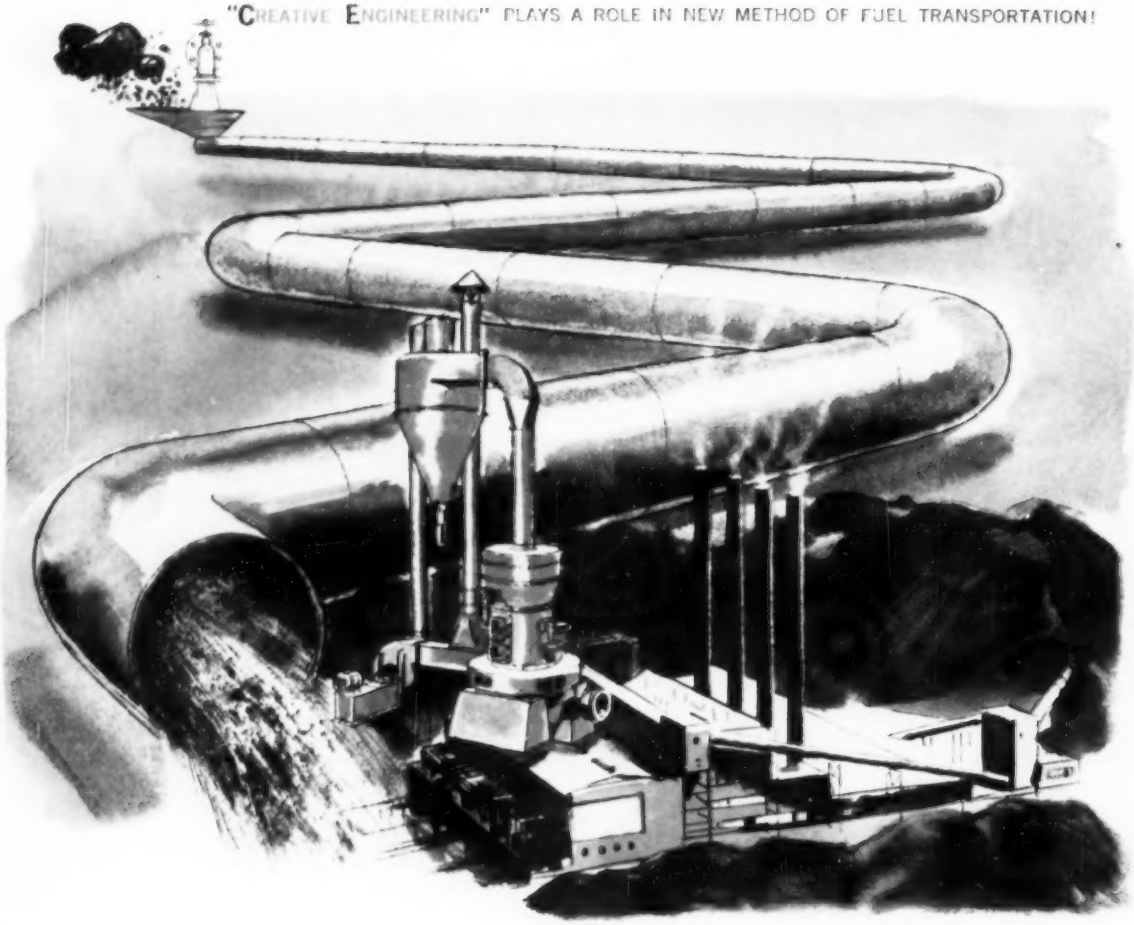
Striking winter view of the Tait Station of the Dayton Power and Light Co.

Economic Trends in Generation ▸

First European Supercritical Plant ▸

Power Plant Clinic ▸

"CREATIVE ENGINEERING" PLAYS A ROLE IN NEW METHOD OF FUEL TRANSPORTATION!



History-making pipeline effects new economies in fuel transportation

The first long-distance coal pipeline in the United States went into regular commercial operation last summer and is now moving coal . . . at a rate of more than 1.25 million tons a year . . . from a mine to a utility power station over a hundred miles away. This history-making pipeline runs from the Georgetown properties of Consolidation Coal Company in eastern Ohio to the Eastlake plant of The Cleveland Electric Illuminating Company near Cleveland. The coal is pumped in the form of a "slurry"—a 50-50 mixture of crushed coal and water.

At the Eastlake plant, the slurry is delivered to dehydrating equipment—including a battery of C-E Flash Drying Systems. Moisture is removed at the rate of 36,000 gallons per hour. The dried coal is then pulverized in C-E Raymond Pulverizers and burned in four mammoth C-E Boilers of the Controlled Circulation type . . . together capable of producing over 4,000,000 pounds of steam per hour.

Once again, C-E equipment plays an important part in an industry's technology—helping to bring new economy to power generation.

"CREATIVE ENGINEERING" is the reason for the leadership attained by C-E products. The products which bear this mark of leadership include:

all types of steam generating, fuel burning and related equipment • nuclear power systems • paper mill equipment • pulverizers • flash drying systems • pressure vessels • soil pipe

COMBUSTION ENGINEERING

Combustion Engineering Building, 200 Madison Avenue, New York 16, N. Y.

C 197

COMBUSTION

DEVOTED TO THE ADVANCEMENT OF STEAM PLANT DESIGN AND OPERATION

Vol. 30 **No. 9**

March 1959

Feature Articles

Economic Trends in the Generation of Electric Energy in the Detroit Edison System
by George A. Porter and Dick E. Hart 30

Steam Power Plant Clinic *by Igor J. Karassik* 39

First European Supercritical Power Plant: Design and Experience, Part I
by G. Noetzlin and A. Engl 43

Abstracts From the Technical Press Abroad and Domestic 49

Editorials

Macroscopic and Microscopic 29

Departments

Advertising Index 60 & 61

COMBUSTION publishes its annual index in the June issue and is indexed regularly by Engineering Index, Inc. and also in the Applied Science & Technology Index.

The magazine is now reproduced and distributed to libraries on microfilm by University Microfilms of Ann Arbor, Michigan.

ROBERT D. TAFT
Business Manager

JOSEPH C. McCABE
Editor

E. ROBERT LaCROSSE
Circulation Manager

GLENN R. FRYLING
Associate Editor

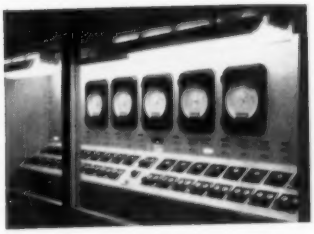
Published monthly by COMBUSTION PUBLISHING COMPANY, INC., 200 Madison Ave., New York 16
A SUBSIDIARY OF COMBUSTION ENGINEERING, INC.
Joseph V. Santry, Pres.; Charles McDonough, Vice-Pres.; Otto Strauss, Treas.; Thomas A. Ennis, Secy.
COMBUSTION is sent gratis to engineers in the U. S. A. in charge of steam plants from 500 rated boiler horsepower up; and to consulting engineers in this field. To others the subscription rate, including postage, is $4 in the United States, $5.50 in Canada, and $8 in Latin America and other countries. Single copies: Domestic, 40 cents. Foreign, 60 cents plus postage. Copyright 1959 by Combustion Publishing Company, Inc. Publication Office, Easton, Pa. Issued the middle of the month of publication.
Acceptance under Section 34.64, P.L. & R., authorized by United States Post Office.

BPA

Printed in U. S. A.

HAGAN NEWSLETTER

Behind the Panel



AUTOMATIC DATA LOGGING FOR NATION'S FOURTH LARGEST WATER SYSTEM

A 158-year-old water works system, taking the first step toward full automation, is installing telemetering and micro-wave facilities to feed data from 92 remote locations throughout their 12 water districts to a Hagan Kybernetes Data Handling system installed in a central building—the Load Control Center. The data includes such items as: water levels, river elevations, pumping rates, pumping pressures, water flow, and other information to provide an operator at the Load Control Center with an instantaneous picture of events throughout the whole water works system.

High and low limits for every point can be fixed from the central system and such off-normal conditions as unexpected level changes, distribution pressure drop, rise in river height will be detected by visible and audible alarms from the Kybernetes system, as well as red printing on the log sheets where the data system is recording all the variables. Normal operation calls for print-out every hour, but it may be obtained at any time—as well as printing special continuous readings on any point experiencing off-normal conditions. Hagan also furnished the main control console and a graphic wall panel. (Item B-1)

HIGH EFFICIENCY DUST COLLECTOR PAYS FOR ITSELF IN TWO WEEKS

Uranium dust in the atmosphere at a uranium ore reduction plant had become an irritating air pollution problem—as well as a source of loss of the valuable ore dust. A Hagan Aerostatic Dust Collector was installed at the rod mill in the plant and has been operating at 97.7% efficiency—recovering so much uranium dust that it paid for itself in two weeks. The collector has shown no signs of wear or tube plugging. In fact, one plant official said, "This is the first mechanical collector I have ever come across that is actually self-cleaning." At another installation where blast furnace slag dust is being collected, the Hagan unit was inspected after 15 months' service. More than 160 tons of abrasive dust had passed through the tube that was cut in half for examination, yet no wear was visible. In fact, most of the mill scale was still intact. (Item B-2)

METER ACCURACY TEST . . . 1 + 1 + 1 + 1 = 1

The odd looking formula above refers to a utility installation where Hagan Ring Balance meters are in service for all principal metering. The first four figures represent four Ring Balance meters which measure these flows: 6th extraction stage, 9th extraction stage, 12th extraction stage and condensate. A fifth meter measures steam flow to the turbine. In other words, the fifth meter measures steam before the turbine while the totals of the other four meters represent steam recovered after the turbine. Ideally, these totals would be the same. At the end of a nine month period the sum of the four meters was compared to the total recorded on the fifth and the figures were within 2.4% of each other, despite the fact that more than three-quarters of a billion pounds of steam had passed through the system over this period. (Item B-3)

SUPER-SONIC MISSILE TESTS IN LESS THAN 30 SECONDS

Snap a huge valve open in a fraction of a second—let a 3000 mph gale blow through for a few seconds—keep this supersonic hurricane constant in a test chamber—all this in less than 30 seconds. Next, volumes of data from brief tests like this are analyzed to know, in advance, if your missile or aircraft is ready for flight. This is what happens in a blowdown wind tunnel where Hagan PowrAmp control systems meet and exceed rigid specifications for split-second accuracy and reliability. At one blowdown tunnel where PowrAmp transducers, amplifiers, computers, electro-hydraulic pilot valves and operators are installed at critical control points, the tunnel was "blown in" for its first test without aid from Hagan engineers, who were available, but were not needed after the PowrAmp equipment had been installed and adjusted. (Item B-4)

HAGAN CHEMICALS & CONTROLS, INC.
Hagan Building, Room 701, Pittsburgh 30, Pa.

If you would like more information on any of the above items, check the appropriate box below.

☐ Item B-1 ☐ Item B-2 ☐ Item B-3 ☐ Item B-4

DAMPNEY COATINGS LIVE WITH IT!

True measure of a high-heat coating's worth is *continuous operation at rated temperature*. Yet many so-called "heat-resistant" coatings take only occasional peaks — fail rapidly in 'round-the-clock service.

Dampney coatings are rated always for day in, day out operation at maximum temperatures. Hold them to it, if schedules call for steady heat, or let them fluctuate to ambient and back. Either way, Dampney silicones and ceramics give you full protection — with plenty in reserve.

Most important, Dampney coatings are selected to meet specific conditions of operation, temperature and corrosive environment. Thus they establish a lasting foundation easily maintained and permanently ending time-consuming and costly surface preparation.

Repeat orders — from a typical customer, 26 in 12 months for enough material to protect 1,929,000 square feet of steel — is the best evidence we have that when industry wants honest high-temperature coatings, it remembers Dampney silicones and ceramics, identified by the two trade names, DAMPNEY and THUR-MA-LOX.

We suggest you do likewise when you want real protection — resistant to 1000 F., to atmospheric corrosion, and to weather exposure — for these industrial hot spots . . .

stacks and breechings	• turbine interiors
steam lines	• precipitators
kilns	• coke ovens
forced and induced draft fans	• incinerators
heat-treating furnaces	• pulverizers
autoclaves and retorts	• blast and open hearth furnaces

Remember, too, the first Dampney trade name and product, known and used today the world around, APEXIOR NUMBER 1 for boiler interiors. For all hot metal, wet or dry, the best protection available is made and marketed by

MAINTENANCE FOR METAL

THE DAMPNEY COMPANY

HYDE PARK, BOSTON 36, MASSACHUSETTS

Coatings for all temperatures to high heat — all corrosive environments.

207

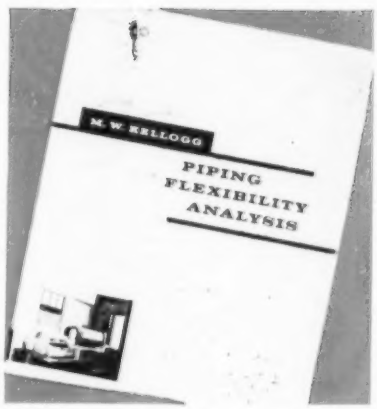
KELLOGG'S PIPE SHOP FABRICATION KEEPS PACE

This complex header for the hot reheat line, here being finished at M. W. Kellogg's Jersey City shops, is an important part of the power piping for Alabama Power Company's Unit No. 3 at Barry, Alabama. This modern steam-electric plant addition in Mobile County is designed for operation at 2000 psi and 1000°F initial temperature; 1000°F reheat. The turbine will supply 225,000 KW.

All power piping for the unit is being fabricated and erected by Kellogg, who will also furnish and install all hangers, guides, anchors, supports, and similar equipment. K-Weld®, Kellogg's unique, inert gas-shielded arc welding technique, is being used on the main steam line and hot reheat lines, and was used in fabricating the header shown above.

Dimensions of the critical steam lines being fabricated of $1\frac{1}{4}$ Cr., $\frac{1}{2}$ Moly. in Kellogg's Jersey City shops are: *Main Steam*—17.5" O.D. x 2.25" minimum wall, and 12.75" O.D. x 1.6875" minimum wall; *Hot Reheat*—26" O.D. x 1.24" minimum wall, and 16" O.D. x 0.8025" minimum wall.

Kellogg welcomes the opportunity to discuss its complete power piping design, fabrication, and erection facilities with consulting engineers, engineers of power generating companies, and manufacturers of boilers, turbines, and allied equipment.



This new 8-page booklet, fully describing Kellogg's electronic computer method of making piping flexibility analysis, has just been published. Write for a copy.

Fabricated Products Sales Division

THE M. W. KELLOGG COMPANY, 711 THIRD AVENUE, NEW YORK 17, N. Y.

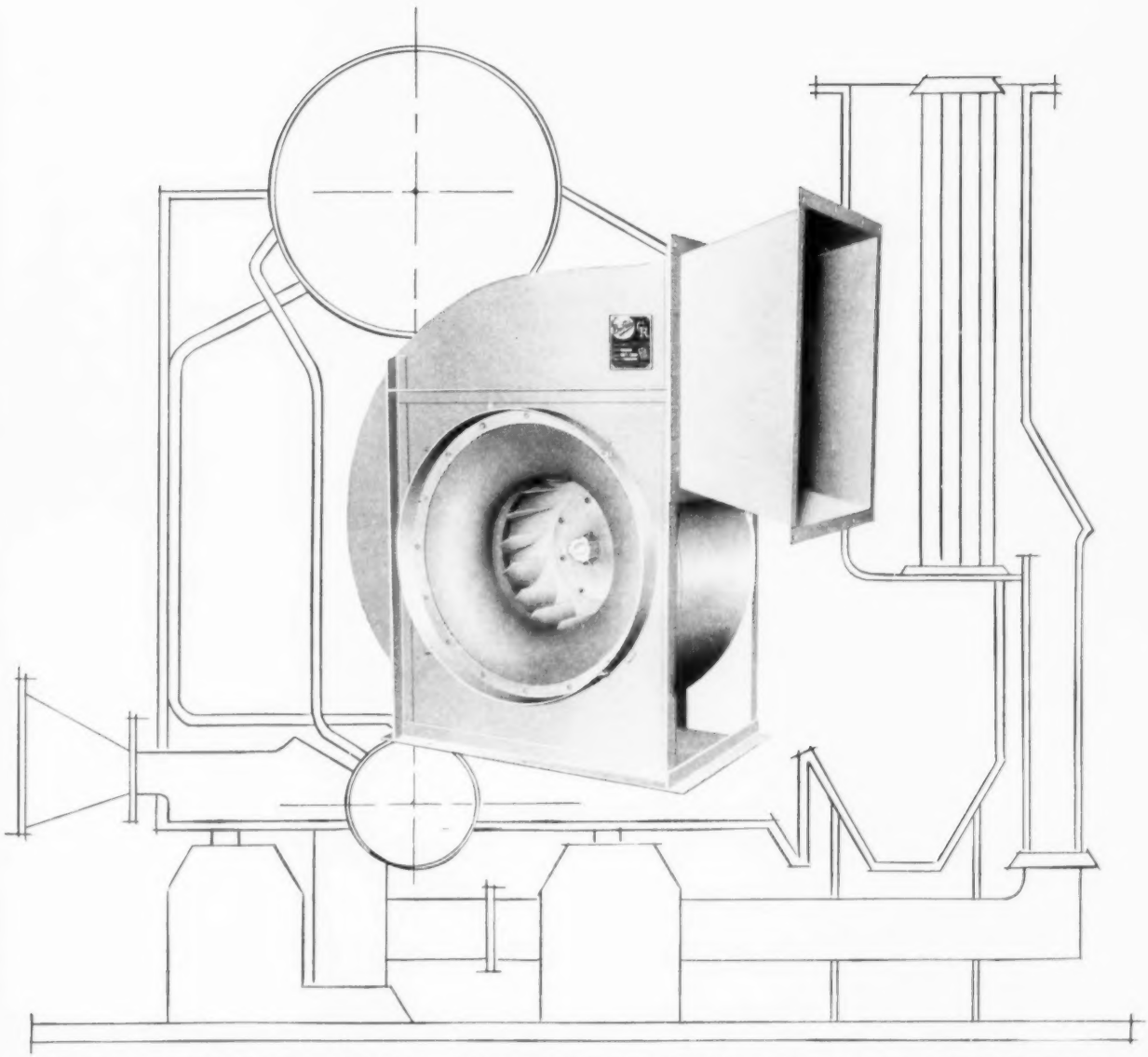
A SUBSIDIARY OF PULLMAN INCORPORATED

The Canadian Kellogg Co., Ltd., Toronto • Kellogg International Corp., London • Kellogg Pan American Corp., New York
Société Kellogg, Paris • Companhia Kellogg Brasileira, Rio de Janeiro • Compañia Kellogg de Venezuela, Caracas

M KELLOGG W

POWER PIPING—THE VITAL LINK

® Registered trademark of The M. W. Kellogg Company



FOR ECONOMICAL MECHANICAL DRAFT SERVICE

"BUFFALO" TYPE "CR" RADIAL WHEEL DRAFT FANS

Combining sharply rising pressure and horsepower characteristics with high static efficiency and resistance to abrasive effects, the "CR" is an ideal fan for stoker-fired or pulverized coal boilers. It is also proving an excellent choice for handling air with dust loadings in a wide range of industrial jobs. Too, these same high-pressure, high-capacity characteristics may mean a smaller fan for many direct-connected applications — a saving in first cost.

Write for Bulletin FD 205 and see the dependable, stable performance built into this husky radial wheel fan for constant volume or inlet-dampered operation. It's one of a *series* of specialized "Buffalo" Draft Fans — including airfoil and backward curve designs with a wide choice of wheels — to give you the best service your operation requires.

NOTE: *Every "Buffalo" Fan has the exclusive "Q" Factor—the built-in Quality which provides trouble-free satisfaction and long life.*

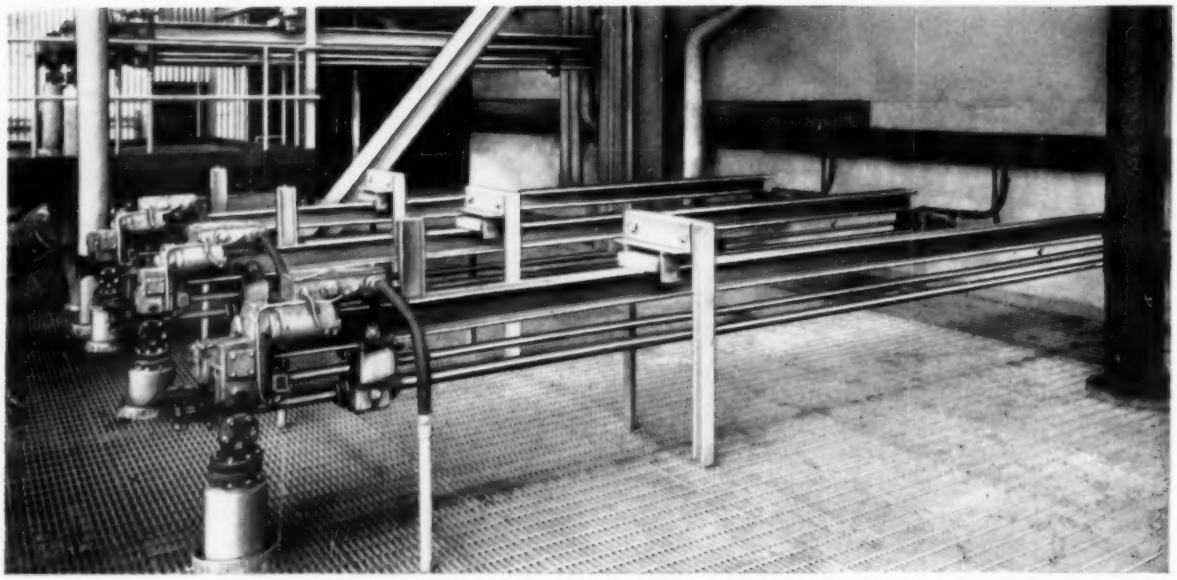
BUFFALO FORGE COMPANY

BUFFALO, N. Y.

Canadian Blower & Forge Co., Ltd., Kitchener, Ont.

"Buffalo"

VENTILATING AIR CLEANING AIR TEMPERING INDUCED DRAFT EXHAUSTING FORCED DRAFT COOLING HEATING PRESSURE BLOWING



Vulcan Automatic-Sequential System controls soot blowing at new Gannon Station

As the first modern utility boiler in Florida to be fired by coal, Tampa Electric Company's Gannon Station incorporates the most advanced control systems. Unit 1, with its boiler rating at 950,000 pounds per hour at 1760 psig and 1000 degrees F., uses a Vulcan soot blowing system that features both group and unit control.

Vulcan T-3-E long retractable soot blowers with their dual-motor drives clean Gannon's Unit 1 boiler with double-helix patterns for complete coverage. The system includes Vulcan wall deslaggers and rotary soot blowers—all driven by electric motors and using steam as the blowing medium. A Copes-Vulcan diaphragm valve reduces steam pressure for blowing and a Copes-Vulcan motor-operated valve is used for shut-off.

A similar Vulcan system will be installed on Gannon's Unit 2, rated at 950,000 pounds per hour at 1760 psig and 1000 degrees F.

Besides fully-automatic soot blowing systems, Copes-Vulcan offers complete systems for controlling combustion, feedwater, boiler feed pump recirculation, and steam temperature. Whether your boiler is large or small, power or process, Copes-Vulcan can provide a unit or an integrated package, custom designed to your requirements.

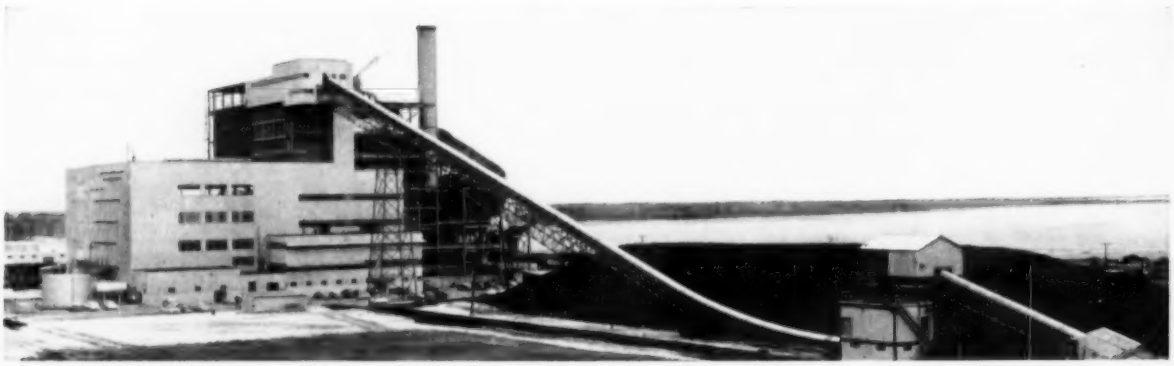
COPES VULCAN

Copes-Vulcan Division

BLAW-KNOX COMPANY

Erie 4, Pennsylvania

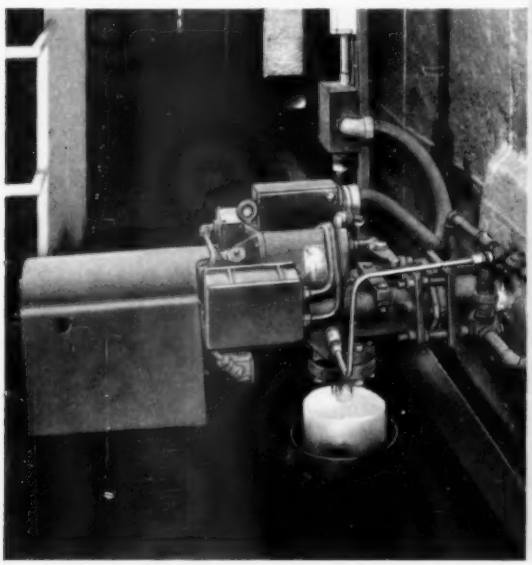
BLAW-KNOX

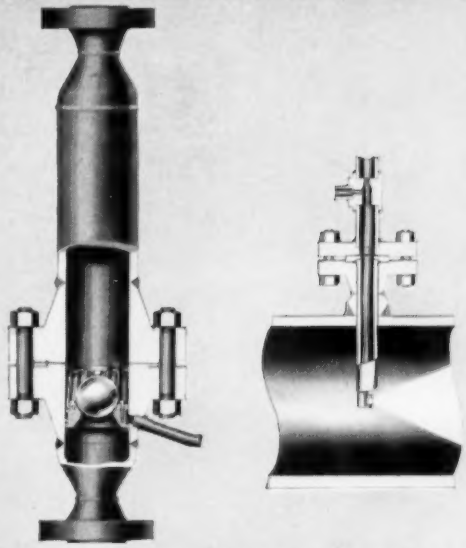


C-V NEWS NOTES

Finger tip control for Gannon's operators . . . with Vulcan's Automatic-Sequential group and unit control. Operator can preselect any number of soot blowers for automatic sequence . . . preselect any number of units or groups of units to be operated individually . . . or switch instantly to single unit operation. Program lights and toggle switches are located on engraved boiler diagram. Automatic-Sequential systems use steam, air or a combination as the blowing medium without a change in equipment. Write for Bulletin 1029.

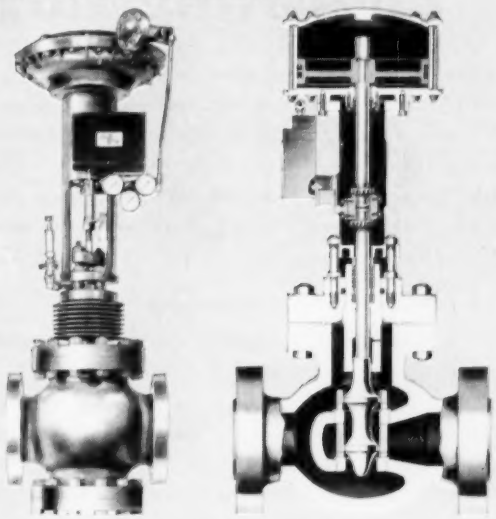
Wall deslagger conserves steam . . . minimizes average slag thickness. Vulcan's RW-3E is equipped with dual motors: one to traverse *fast* to get the nozzle to and from the blowing position almost instantly . . . the other to rotate the tube slowly for thorough cleaning. The RW-3E may be installed indoors or out, at almost any angle from side wall, roof or floor. It has only one outside stuffing box, no threads or working parts in the blowing medium to assure easy maintenance. Write for Bulletin 1034.





Desuperheaters improve temperature control. Variable-Orifice Desuperheater* (left) uses a weighted steel ball to control orifice opening . . . holds reduced steam temperature constant only twenty feet downstream from desuperheater outlet, even over a 50-to-1 load range. Bulletin 1037. *Patent Applied For

Steam-Assist (right) meets all specifications for conventional steam-atomizing type yet normally uses assisting steam only on light loads where control is most difficult. Mechanical-atomizing types also available. Bulletin 1024-A.



Versatile regulator valves offer new simplicity of design. Diaphragm-type CV-D (left) is designed for remote control service. It can be direct or reverse acting, has excellent rangeability. Piston-type CV-P (right) is designed for high-duty service . . . assures maximum power with precise positioning.

All Copes-Vulcan valves are tailored to the job. The style of valve port is selected to provide optimum control for specified operating conditions. Bulletin 1027.

Bailey Meters and Controls for Combustion, Feed Water, Steam Temperature and Condensate at Moores Park Station, City of Lansing, Michigan.

How Bailey makes steam operating duties a pleasure—

Fingertip Controls, convenient indicators and trend recorders make steam control room operating duties a pleasure. You get this bonus for your operators when you specify Bailey Meters and Controls.

Bailey is the choice of virtually all the most efficient plants on the Federal Power Commission's heat rate report. Here's why:

1. A Complete Line of Equipment

You can be sure a Bailey Engineer will offer the right combination of equipment to fit your needs.

Bailey manufactures a complete line of standard, compatible pneumatic and electric metering and control equipment that has proved itself. Thousands of successful installations involving problems in measurement, combustion, and automatic control are your assurance of the best possible system.

2. Experience

Bailey Engineers have been making steam plants work more efficiently for more than forty years. Veteran engineer and young engineer alike, the men who represent Bailey, are storehouses of knowledge on measurement and control. They are up-to-the-minute on the latest developments that can be applied to your problem.

3. Sales and Service Convenient to You

There's a Bailey District Office or Resident Engineer close to you. Check your phone book for expert engineering counsel on your steam plant control problems.

AI33-1

BAILEY METERS

Instruments and controls for power and process

BAILEY METER COMPANY

1025 IVANHOE ROAD • CLEVELAND 10, OHIO

In Canada—Bailey Meter Company Limited, Montreal

Hall Industrial Water Report

VOLUME 7 MARCH 1959 NUMBER 2

Let's Keep Steamed Up

Large or small, the boiler house is the heart of most industrial plants. It must make steam to maintain production. When there is trouble, production losses from lack of process steam or power may be far more costly than the actual repairs.

Water problems are high on the list of the causes of unscheduled boiler house outages. To minimize these problems, skilled Hall engineers are ready to help you establish a sound, practical water conditioning program. And they can help you with other water problems in cooling systems, process operations and waste disposal.

Spreading Oil on the Water

Due to construction work, a small plant had only one boiler available. Then a fuel oil heater sprung a leak. Suddenly the one boiler had about 200 gallons of oil in it.

Ordinarily the boiler would have been shut down for a complete cleaning. However, that was not considered possible at the time of the accident. Recognizing that he was in real trouble, the engineer called Hall Laboratories.

Fast action was necessary. Most of the oil had to be removed from the boiler without taking it out of service for more than a few hours at night. Hall engineer C. F. Raines fed large quantities of caustic soda and wetting agent while lightly firing the boiler, venting steam to the atmosphere and blowing down heavily. Then the boiler was overflowed through the vent. This took from midnight until 4:00 a.m.

When the boiler was put back on the line at 5:30 a.m., the usual zeolite-treated feedwater was replaced with hard raw water so sludge to absorb oil would be produced in the boiler water. Several days later there was time over a week-end to do a more complete boiling-out job.

In spite of the heavy oil contamination the emergency action kept the boiler in service. Furthermore, when a quick inspection was made after the week-end boil-out there was no evidence of oil on the internal surfaces.

Well Water Changes For the Worse

About three years ago there was a radical change in the well water used by an eastern town. Hardness soared from a constant 8 to 9 gpg to a fluctuating 25 to 40 gpg.

A small local factory had successfully used the softer well water for boiler feedwater by pretreating it with lime and soda ash in a hot-process softener. Trouble came with the new well water because the widely fluctuating, high hardness made adequate control of chemical feeds well-nigh impossible. Calcium carbonate deposition completely plugged the vent condenser on the deaerating heater and stopped a feed pump by causing it to bind.

Hall engineer F. R. Duesing recognized that water conditioning procedures would have to be adjusted to accommodate fluctuating hardness of the feedwater. He therefore used a dispersive to stop the deposition of calcium carbonate in the pre-boiler system. This was the answer. After more than two years' operation there has been no further scale formation on the feed pumps or deaerator vent condenser.

Blowdown was another problem. It was excessively high because of the high solids concentration of the treated well water. By instituting the use of Hagan C-1 Antifoam, Duesing was successful in doubling the normal concentration of dissolved solids in the boiler water without impairment of steam quality. Subsequent inspections of the turbine and boiler superheaters have confirmed that steam quality is good.

Removing Old Scale From Boilers

Scale forms in a boiler in response to specific physical and chemical circumstances. Significant changes in water composition, chemicals used for conditioning, or amounts of chemicals fed can cause the scale to slough off. Accumulation of loosened scale can then upset circulation, obstruct blowdown connections, plug tubes and headers and result in unsafe operation and repairs.

To avoid trouble, a plant with dirty boilers should preferably clean them mechanically or chemically before changing to a more effective water conditioning program. If this is not possible for some reason, such as steam load requiring that all boilers be kept in service, the recommendations of the Hall engineer should be closely followed. He will base his recommendations for establishing desired boiler water conditions on his experience in getting rid of old deposits slowly enough to avoid serious difficulty.

Thermocouples Tell Tube Failure Story

Thermocouples, used to record tube temperatures, were resorted to by a midwest paper mill to warn of scale deposition in the water walls of their boiler. Sludge and sodium aluminum silicate (analcite) scale had caused trouble, and zeolite softening of makeup water didn't stop the analcite. Readings showed tube temperatures went from 450F to over 550F in 60 days.

Hall engineer M. L. Mitchell recommended a newly developed Hagan dispersive which is especially effective in promoting tube rinsing in regions of high heat transfer. The results were dramatic. Tube temperatures leveled off and when the boiler was next cleaned, continued use kept temperatures at normal levels.

Water is your industry's most important raw material. Use it wisely.

Industrial Water Problems Require Special Handling

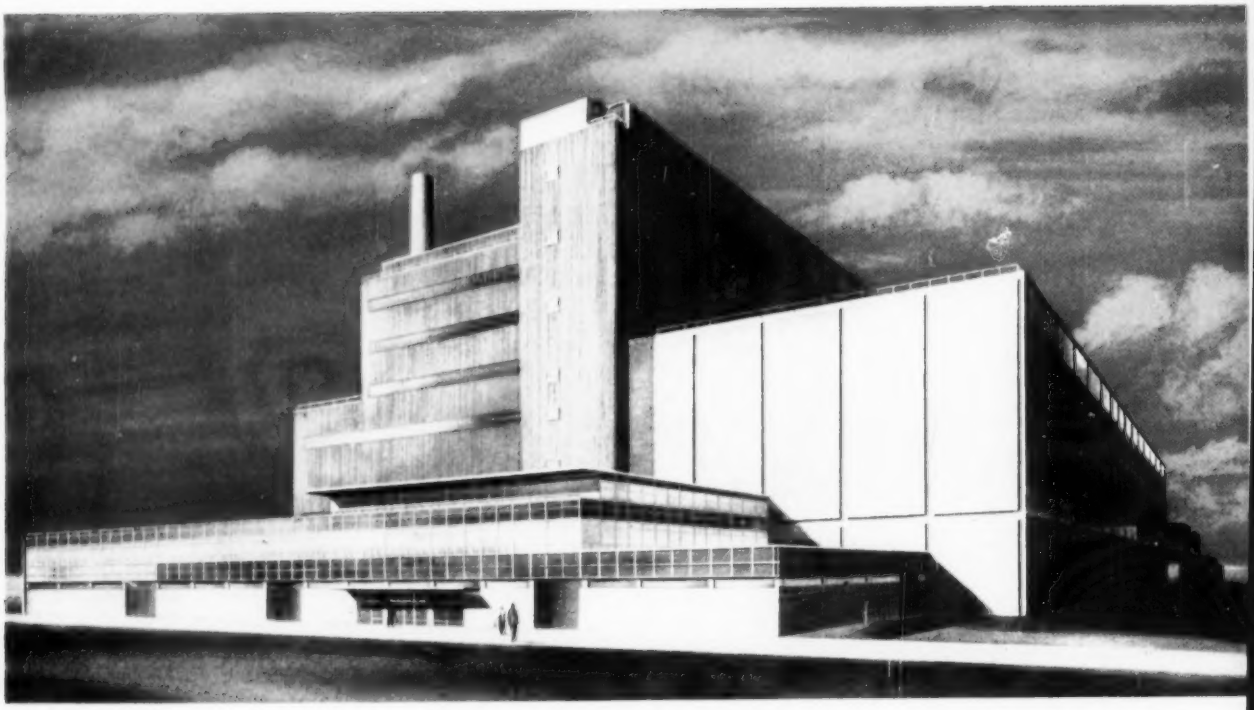
There are no "stock answers" to industrial water problems. For information on how the Hall System can help you solve your particular water problems, write, wire or call address below:

HALL LABORATORIES

DIVISION OF HAGAN CHEMICALS & CONTROLS, INC.
HAGAN BUILDING, PITTSBURGH 30, PA.
In Canada: Hagan Corporation (Canada) Limited, Toronto

Hall Laboratories—Consultants on Procurement, Treatment, Use and Disposal of Industrial Water

Power Station



High point of steam power progress in 1959

Now nearing completion, and scheduled for service this year, is the Eddystone Plant of Philadelphia Electric Company, which is expected to establish new standards of steam power efficiency. The initial boiler is a C-E Sulzer Monotube Steam Generator, designed to deliver steam at 5000 psi throttle pressure and 1200 F — the highest steam conditions adopted to date. It will serve a 325,000-kw turbine-generator.

COMBUSTION

Combustion Engineering Building

ALL TYPES OF STEAM GENERATING, FUEL BURNING AND RELATED EQUIPMENT, NUCLEAR REACTORS,

trends revealed

by C-E Boilers placed in service in 1958

A significant milestone in electric utility history was reached last year when privately-owned generating capacity passed *100,000,000* kilowatts. This happened on May 11 when the C-E-powered, 75,000-kw unit at Station No. 4, Tucson Gas, Electric Light and Power Company, went on the line.

Last year also witnessed important progress in the economy of power generation as reflected in the trends toward higher steam pressures and unit capacities. These trends are impressively revealed by the following data of C-E Boiler installations – representing a total capacity of more than 5,000,000 kw – placed in service in 1958.

TREND TO 2400 PSI

The growing trend to 2400 psi throttle pressure was highlighted by the fact that 9 C-E Boilers in this pressure range went on the line during the year. These units alone account for *1,424,000 kw*. All but two of them are of the controlled circulation design; the two exceptions are C-E Sulzer Monotube Steam Generators.

TREND TO BIG UNITS

The previously-indicated trend to really big units began to make itself felt. Two of the C-E Boilers installed in 1958 serve turbine-generators of 325,000-kw capacity, and four additional units for this capacity are on order. Also on order are two larger units – one for 340,000 kw and one for 500,000 kw. Two of the six 325,000-kw units are C-E Sulzer Boilers for *supercritical* pressures.

CONTINUING TREND TO CONTROLLED CIRCULATION

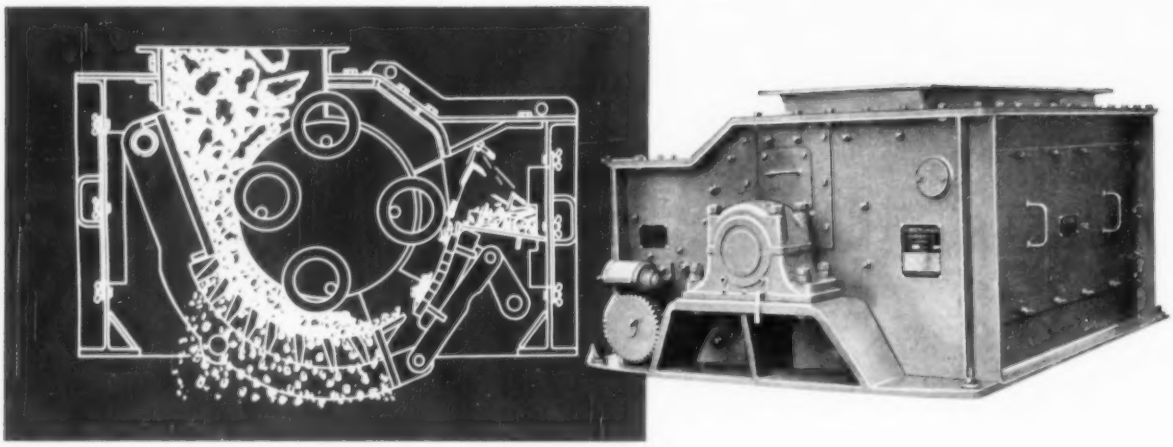
Controlled Circulation continues to enjoy widespread acceptance for high-pressure utility boilers... particularly those in the 2400-psi range. 110 C-E Controlled Circulation Boilers have thus far been purchased by domestic utilities to serve an aggregate turbine capacity of 19,752,000 kw. Of these, 67 are now in service – with a total capacity of nearly 11-million kw. An additional 23 units, with total capacity of 5,030,750 kw, have been ordered from C-E, its associates or licensees, for installations outside the United States.

ENGINEERING

C-199

200 Madison Avenue, New York 16, N. Y.

PAPER MILL EQUIPMENT · POWDERIZERS · FLASH DRYING SYSTEMS · PRESSURE VESSELS · SOIL PIPE

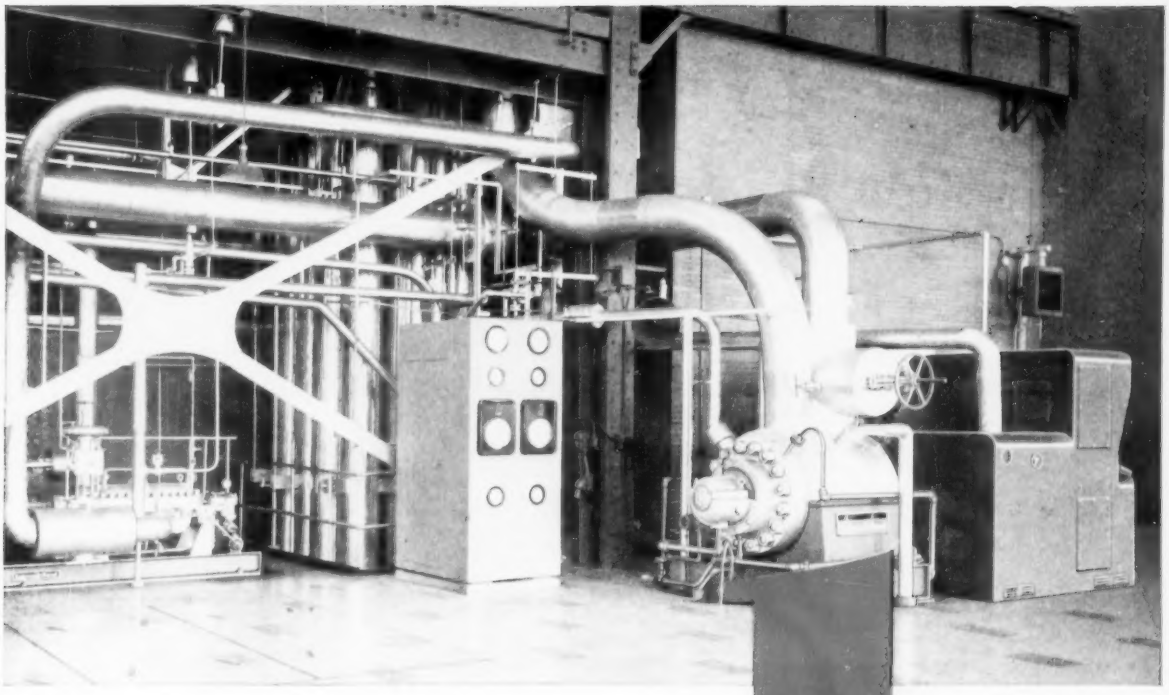


TRAMP IRON FALLS INTO A TRAP

When preparing coal with the Pennsylvania Ring Granulator you've automatically eliminated any chance of tramp iron causing trouble. This is due to the tramp iron trap in the Granulator. Any outlaw material too large to pass through the cage bars is carried on across the cage bar area and dropped into the tramp iron pocket. A curved deflector plate prevents the unwanted material from continuing around the rotor and entering the crushing cycle again, or shooting out the hopper. This great crusher has a lot more features that have given it leadership wherever coal is crushed. Bulletin 9004 gives you complete details. Ask for it. Pennsylvania Crusher Division, Bath Iron Works Corporation, West Chester, Penna.

Penn CRUSHER

PE-510



FULL-CAPACITY PUMPS... ONE per boiler

I-R High-Speed Boiler-Feed Pump at Appalachian Power Company's Glen Lyn Station is the first of 8 Identical I-R Units installed on the American Electric Power System

The Ingersoll-Rand boiler-feed pump shown above represents a radical departure from previous central station practice. Instead of the usual three-pump arrangement with two normally carrying full load, in this installation one main pump supplies all the feedwater required for the 225 MW Glen Lyn Unit No. 6. This unit first operated in May 1957. The last of seven more I-R full capacity boiler-feed pumps like the one shown above is currently being installed.

In addition to making important savings in first cost and operating cost, the turbine-driven full-capacity pump improves cycle performance and heat balance conditions by using extraction steam from the main turbine to drive the pump and exhausting this steam to feedwater heaters.

Each pump, rated 1,500,000 lb hr at 2400 psig and 5400 rpm, is driven directly by a General Electric turbine. Pumps are of 4-stage, double-case construction with "Unit-Type" rotor assembly and floating-ring type stuffing boxes. Boiler start-up is handled by a smaller auxiliary motor-driven I-R feed pump, barely visible in the left background above.

In addition, American Electric Power will soon put into operation the *world's largest* boiler-feed pumps—two 22,000 hp I-R full capacity units serving new 450 MW generators at two AEP stations.

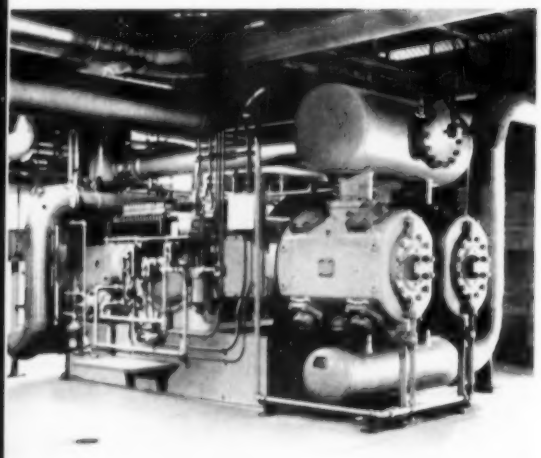
For further details on full-capacity boiler-feed pumps, or any other boiler-feed units, contact your Ingersoll-Rand sales engineer.

Ingersoll-Rand
11 Broadway, New York 4, N. Y.

COMPRESSORS • GAS & DIESEL ENGINES • PUMPS • AIR & ELECTRIC TOOLS
CONDENSERS • VACUUM EQUIPMENT • ROCK DRILLS

Specifies AIR for furnace and tube bank

. . . another installation of Cooper-Bessemer compressors for soot blowing service



Typical installation of Cooper-Bessemer FM air compressors for soot blowing service—El Segundo Station of Southern California Edison Company. This unit is rated 500 hp at 400 rpm.

On the banks of the Wabash, the new Breed Station of Indiana & Michigan Electric Company will stand out as a symbol of sound, far-sighted engineering. Designed by and built under supervision of the American Electric Power Service Corporation, this 450 megawatt steam generating station will embody the latest advances in power plant methods and equipment. Take furnace and tube bank cleaning for example . . .

The Cyclone-fired furnace of this modern station will be cleaned by compressed air. Three 600 hp Cooper-Bessemer Type FM compressors will deliver a total of 6100 cfm for soot blowing service.

One after another, power companies and their consultants are specifying this improved method of boiler cleaning as the solution to many problems. And for authoritative advice and the latest in facilities, they are turning to Cooper-Bessemer. Soot blowing is one of the many fields in which Cooper-Bessemer is able to render an outstanding service. Write for complete details.

BRANCH OFFICES: Grove City • New York • Chicago • Washington • San Francisco • Los Angeles • Houston • Dallas • Odessa • Pampa • Greggton • Seattle • Tulsa • St. Louis • Kansas City • Minneapolis • New Orleans • Shreveport

SUBSIDIARIES: Cooper-Bessemer of Canada, Ltd. . . . Edmonton • Calgary • Toronto

Cooper-Bessemer International Corporation . . . New York • Caracas • Mexico City

Cooper Bessemer

GENERAL OFFICES: MOUNT VERNON, OHIO

ENGINES: GAS - DIESEL - GAS-DIESEL
COMPRESSORS: RECIPROCATING AND CENTRIFUGAL
ENGINE OR MOTOR DRIVEN

cleaning at new Breed Station

ECONOMICS OF BOILER CLEANING WITH COMPRESSED AIR

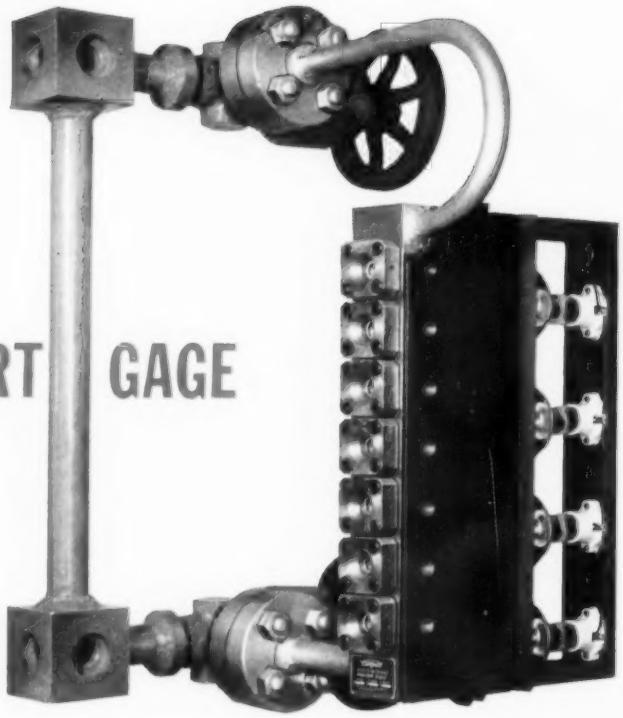
(Versus Steam)

1. Pressure is always adequate to do clean, thorough job.
2. Better programming with air . . . gets better cleaning results for higher boiler efficiency.
3. Lower cost for blowing medium . . . less waste.
4. No quenching action on hot alloy tubes or pressure vessels.
5. Less maintenance of blower equipment due to erosion, corrosion, packing wear.
6. Improved housekeeping . . . no steam or condensate leakage.
7. Greater over-all economy of blowing medium on evaluated basis.
8. Eliminates condensate makeup required when blowing with steam.

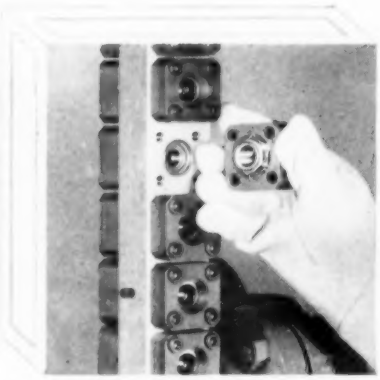
DATA—Write for free copy of "Steam or Air: Which costs more for boiler cleaning?"

Breed Station of Indiana & Michigan Electric Company, located in western Indiana. Designers: American Electric Power Service Corporation.

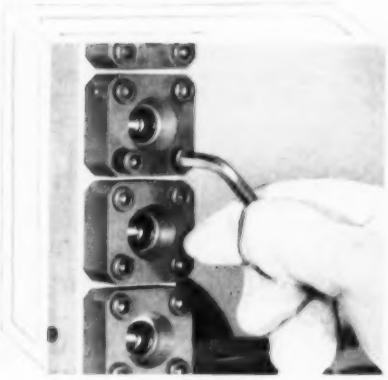
servicing the new YARWAY COLOR-PORT GAGE is easy as a b c



a Remove four cap screws and lift off cover assembly (held in right hand). Install new port assembly (glass-mica-gasket, shown in left hand) in cover. This port assembly is part of the complete cover assembly.



b Re-install complete cover assembly. Sealing gasket automatically seats in gasket groove in body.



c Tighten down four Allen cap screws with standard wrench (no torque wrench required).

New Yarway Color-Port Boiler Water Level Gages (for pressures to 3000 psi.) offer not only this new ease of maintenance but insure brilliant red and green readings of steam and water.

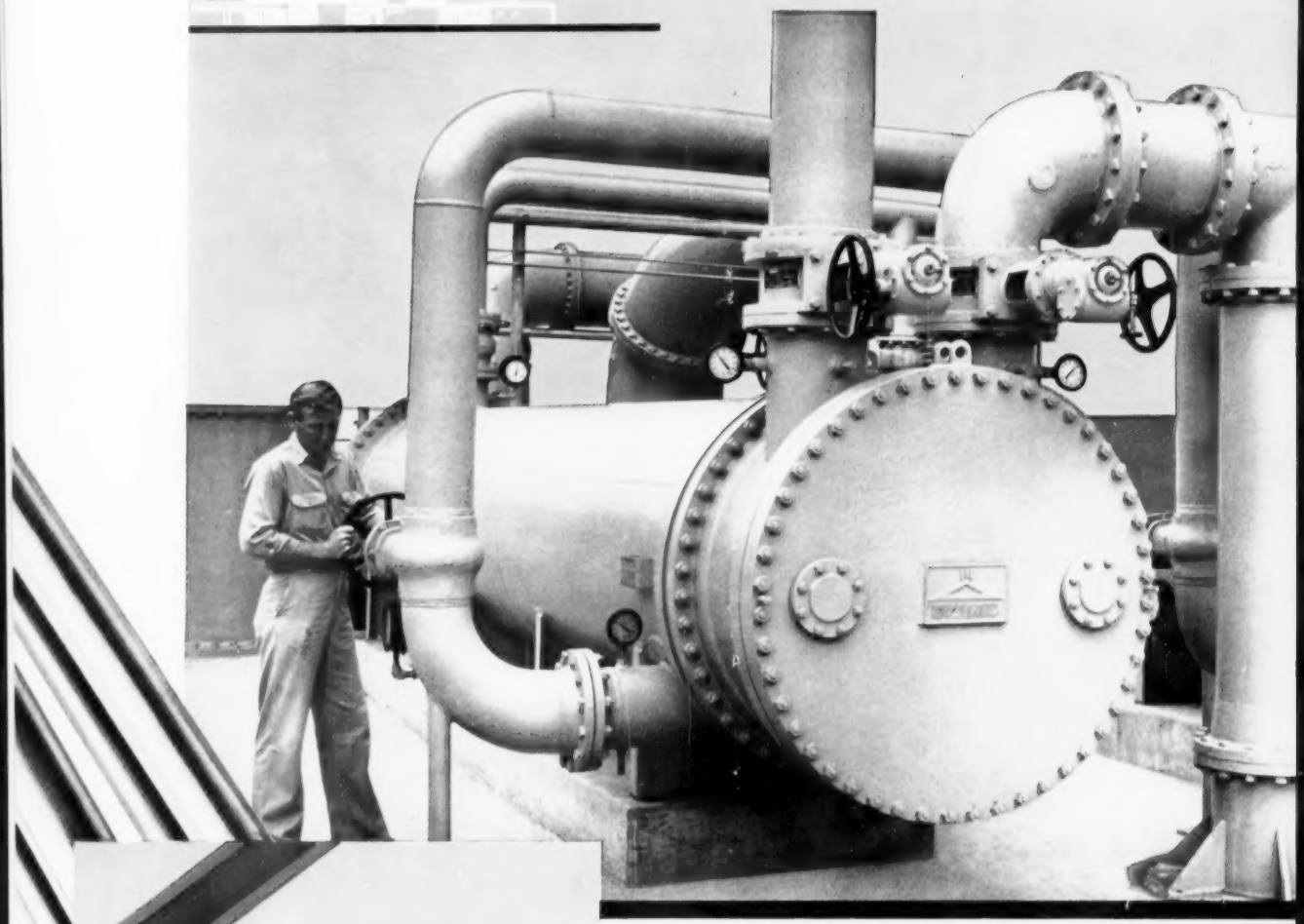
For full details, write for Yarway Bulletin WG-1814.

YARNALL-WARING COMPANY, 100 Mermaid Ave., Philadelphia 18, Pa.
Branch Offices in Principal Cities

GO YARWAY WITH CONFIDENCE

where trouble-free performance is a matter of pride...

SAN DIEGO GAS & ELECTRIC COMPANY
ENCINA PLANT CALIFORNIA



SCOVILL

heat exchanger tube

San Diego Gas & Electric Company's Encina Plant in Carlsbad, California, has been expanded into one of the larger and most modern steam turbo-generator stations on the West Coast.

Scovill Aluminum Brass Heat Exchanger Tube is installed in condensers and heat exchangers serving all three of Encina's 106,000 KW turbo-generator units. Here, as elsewhere in the Nation's finest power plants, operating engineers have found Scovill Heat Exchanger Tube and Scovill Heat Exchanger Technical Service dependable and efficient aids to trouble-free performance.

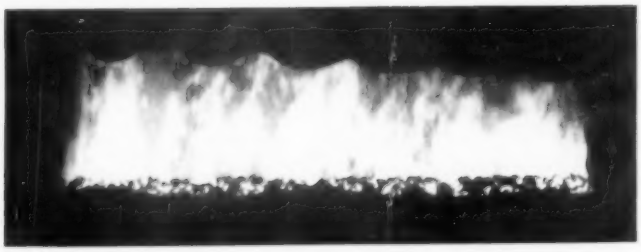
These Scovill services are no farther away than the phone on your desk.

HEAT EXCHANGER TUBE for Applications from Marine to Petrochemical, from Compressor Intercoolers to "Cat Cracker" Exchangers, in these popular Alloys . . . Phosphorized Admiralty • Admiralty • Arsenical Admiralty • Red Brass, 85% • Deoxidized Copper • Arsenical Copper • Cupro-Nickel, 10%-20%-30% • Aluminum Brass • Aluminum Bronze, 5% • Muntz Metal • Duplex Tube

SCOVILL MANUFACTURING COMPANY, Mill Products Division, 99 Mill Street, Waterbury 20, Conn. Phone PLaza 4-1171.

48C-59

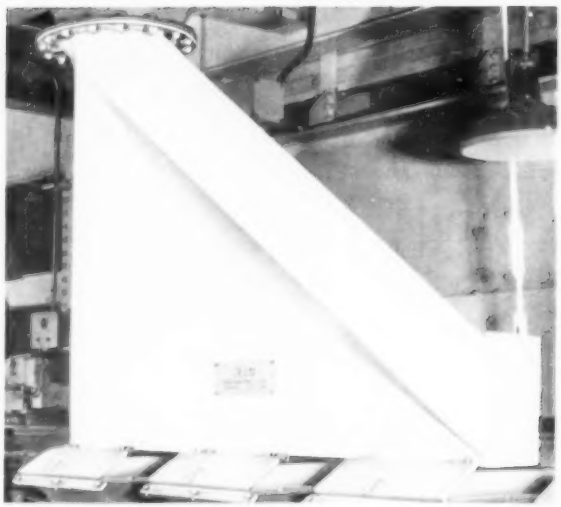
Look at the fire on your stoker



• Coal segregation on your stoker means increased costs due to uneven combustion. Fine coal zones present greater resistance to air flow. Insufficient air means incomplete combustion, unburned fuel in the ash pit. In addition, these zones produce more than the customary amount of smoke.

Coarse coal zones, on the other hand, present less resistance to air flow. More air than required means low CO_2. Also, uncovered stoker iron is exposed to high furnace temperature. Result — expensive repairs and down time.

Take another look at your stoker fire. If you see the tell-tale signs of segregation, you need a S-E-Co. CONICAL Non-Segregating Coal Distributor. This distributor has effectively eliminated coal segregation in hundreds of plants throughout the country. For more information on how you can increase the efficiency and economy of your stoker, write for our Bulletin No. 73. Remember, in scales, valves or distributors, you get more value when you buy S-E-Co.



A graphic description of the principle of the S-E-Co. CONICAL Non-Segregating Distributor (pictured above) is found in our Bulletin No. 73. Write now for your copy.

SPECIALISTS IN BUNKER TO PULVERIZER AND BUNKER TO STOKER EQUIPMENT

STOCK Equipment Company

731-C HANNA BLDG., CLEVELAND 15, OHIO

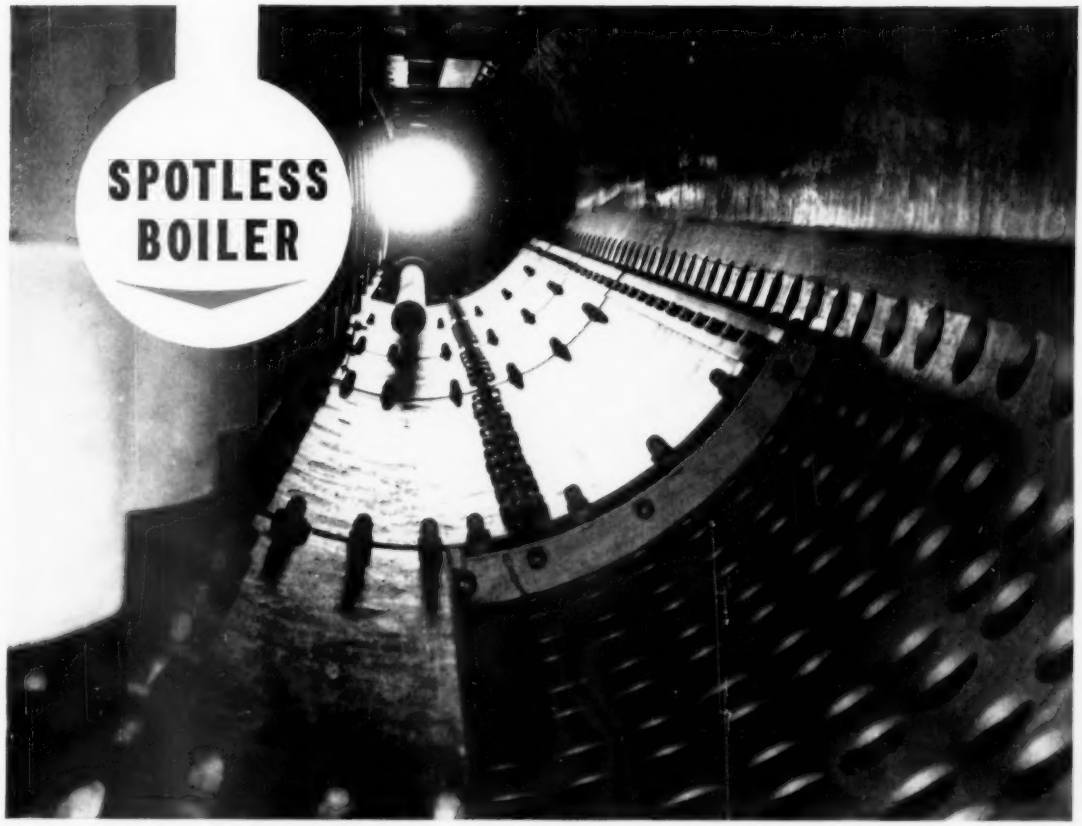
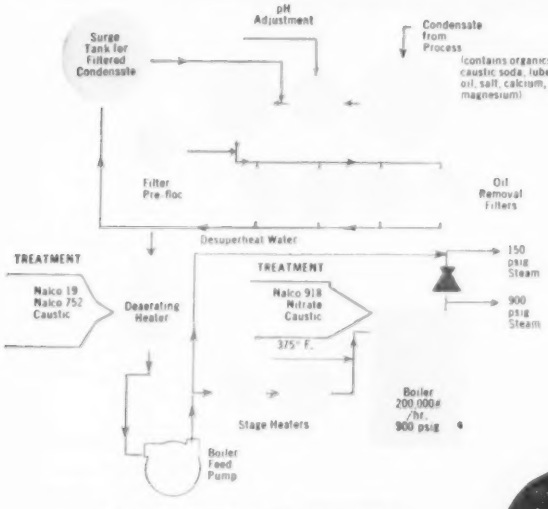


PHOTO COURTESY OF THE DOW CHEMICAL CO.

even though it operates on Contaminated Condensate!



FEEDWATER FLOWSHEET...
Pittsburg, California Plant of The Dow Chemical Co.

Nalco's continuous advisory service, easily as important as chemicals in solving this problem of contaminated condensate, simply doesn't fit into a chart. Consulting Service, in any water conditioning program, complements equipment and specialized services. It is part of the Nalco package . . . of results!

Contaminated condensate from process systems presents a complex water conditioning problem for boiler plant operators. In this system the solids in raw condensate run 15 to 80 ppm. Contaminants are lube oil and other hydrocarbons, caustic soda, salt, and traces of calcium and magnesium . . . a topnotch formula for promoting scale and sludge formation.

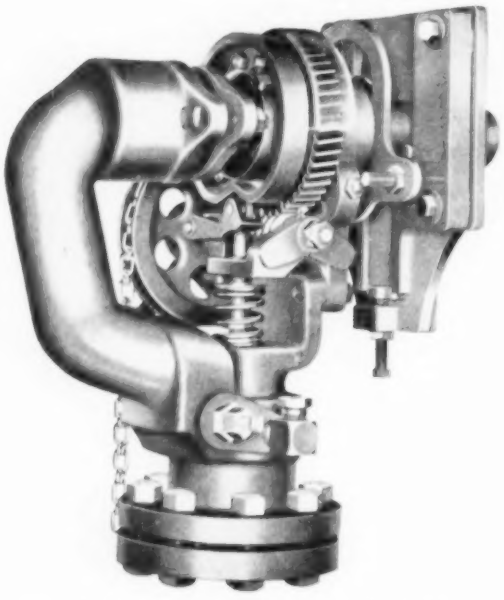
Working closely with a superbly cooperative plant operating staff, a Nalco Representative developed the water treatment plan. He provided the continuous counsel and coordination that keeps the boiler as it is shown here: free of sludge and scale . . . clean-to-metal after a full year's operation.

You, too, can count on the Nalco System for permanent, economical answers to water treating problems. Write or 'phone for details.

NATIONAL ALUMINATE CORPORATION
6234 West 66th Place Chicago 38, Illinois
Northwestern United States, Hawaii and Alaska: The Flox Co., Inc., Minneapolis 3, Minnesota
Canada: Alchem Limited, Burlington, Ont.
Italy: Nalco Italiana, S.p.A.
Germany: Deutsche Nalco-Chemie GmbH.
Spain: Nalco Espanola, S.A.

Nalco

SERVING INDUSTRY THROUGH PRACTICAL APPLIED SCIENCE



Quick Opening Bayer Soot Blower Valves Assure

- 100% cleaning efficiency
- minimum steam consumption
- superior high temperature resistance

The Bayer Balanced Valved Soot Blower is a single-chain operated design that assures precise sequential operation of the valve and element. *Only* after the start of full steam flow does element rotation commence—a feature which provides positive and efficient cleaning over the entire arc. . .without wasting steam.

The Bayer Soot Blower is simply operated by a pull on the chain which opens the cam-actuated valve. Continued pulling of the chain slowly rotates the element through its cleaning arc, at the end of which the valve automatically closes.

For severe high temperature locations, "super service" elements of Bayer-developed "Chronilloy" are available. Of superior strength, wrap-resistance, and stability, these elements resist the oxidation and chemical action caused by very high temperature gases.

In over fifty years of continuous specialized service, the Bayer company has equipped more than 35,000 boilers with dependable soot blowers. Engineered for long life and low maintenance, Bayer products assure economical and trouble-free operation.

ADVANTAGES OF THE BAYER BALANCED VALVED SOOT BLOWER

- single chain operation
- individual elements adjustable for high pressure service by orifice plate valve
- full steam pressure over entire cleaning arc
- selected gear ratios for optimum rate of element rotation
- minimum pressure drop through valve body
- machined air seal with spring loaded seat
- complete vacuum breaker protection
- precision swivel tube alignment lessens stuffing box packing needs
- load carried on ring type thrust bearings

For further information contact the Bayer representative nearest you. He is an experienced engineer, qualified to service Bayer Soot Blowers.

Agencies

New York	Cleveland	Boston	Los Angeles	Charlotte	Salt Lake City	Washington, D.C.
Philadelphia	Detroit	Seattle	Cincinnati	Richmond	Houston	Atlanta
Chicago	Pittsburgh	St. Paul	Indianapolis	Denver	Kansas City	Tulsa

The BAYER COMPANY

4030 Chouteau Avenue, St. Louis 10, Missouri

pressure seal gate valves ... made the POWELL way

600, 900, 1,500, 2,500 Pounds
and Higher—all commercial sizes

Powell Pressure Seal Gate Valves offer many superior features. A few are:

- Streamline flow passage makes possible maximum flow with minimum turbulence.
- Outstanding simplicity of design, smooth body contour and weight reduction assure easier installation, greatly reduced insulating costs, and a marked saving in space.

Powell Pressure Seal Valves are also available in Globe, Angle and Check patterns.

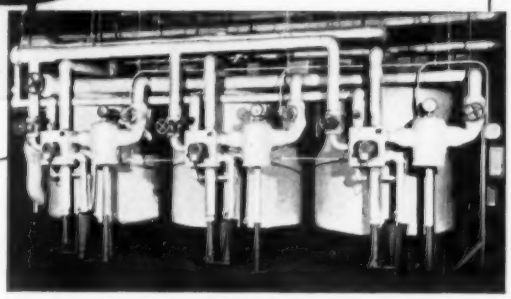
For all your valve needs, consult your local Powell distributor—or write directly to us.

THE WM. POWELL COMPANY
Cincinnati 22, Ohio
Dependable Valves Since 1846

POWELL...world's largest family of valves

Progress in water conditioning . . .

soften water *Automatically* with a COCHRANE sodium zeolite system



The Sodium Zeolite process is the simplest, most popular means of converting hard water to soft water for industrial use. No chemicals are added, no precipitates formed, yet zero hardness water is produced.

Cochrane's exclusive Hydromatic Single Control Valve makes the Zeolite process even simpler, more reliable and more economical. This Single Control Valve takes the place of 6 or more gate valves of the old-fashioned design. Operation can be manual, semi-automatic or completely automatic.

Check these advantages of Cochrane Hydromatic Valves:

- The cast iron split-case valve body is new in design with removable cover. This permits larger, smoother internal passageways resulting in lower loss of head. It also permits easy access to the inner valves and seats without disconnecting piping.
- Inside the body are the six inner single seat diaphragm valves hydraulically actuated by a rotating multiport pilot valve. For automatic control a 40 watt motor drives the pilot shaft through a gear. These non-leaking, non-scoring inner valves with compressible rubber valve discs prevent contamination of treated water by brine or raw water.
- Automatic control of backwash and rinse flow rates even with variable raw water pressure—eliminates rate-of-flow controllers or float operated butterfly valves behind orifices in large concrete sumps.
- Slow valve action prevents hydraulic shock to zeolite or supporting bed and piping.

Wherever Sodium Zeolite Softening is indicated, Cochrane's experience and superior equipment design assure top performance. For more information on Cochrane Sodium Zeolite Softeners, write for Publication 4520-D.

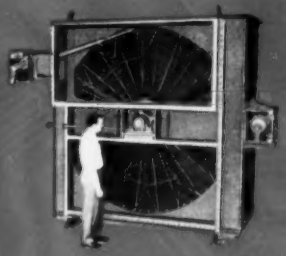
Cochrane
CORPORATION
3109 N. 17th Street, Philadelphia 32, Pa.
Philadelphia • New York • Chicago
Cochrane Water Conditioning, Limited, Toronto, Montreal, Winnipeg, Canada.

Representatives in thirty-two principal cities in U.S., Hawaii, Puerto Rico; also Havana, Cuba; Paris, France; La Spezia, Italy; Mexico City, Mexico; Caracas, Venezuela; Santiago, Chile; Manila, Philippine Islands.

POTTSTOWN METAL PRODUCTS DIVISION—
Custom built carbon steel and alloy products.

Demineralizers • Zeolite Softeners • Hot Process Softeners • Hot Lime Zeolite Softeners • Dealkalizers • Reactors • Deaerators • Pressure Filters
Continuous Blowoff Systems • Condensate Return Systems • Steam Specialties

Here's what you can do about the high cost of fuel.



Get the same heat from cheaper fuel with a

LJUNGSTROM® PACKAGE AIR PREHEATER

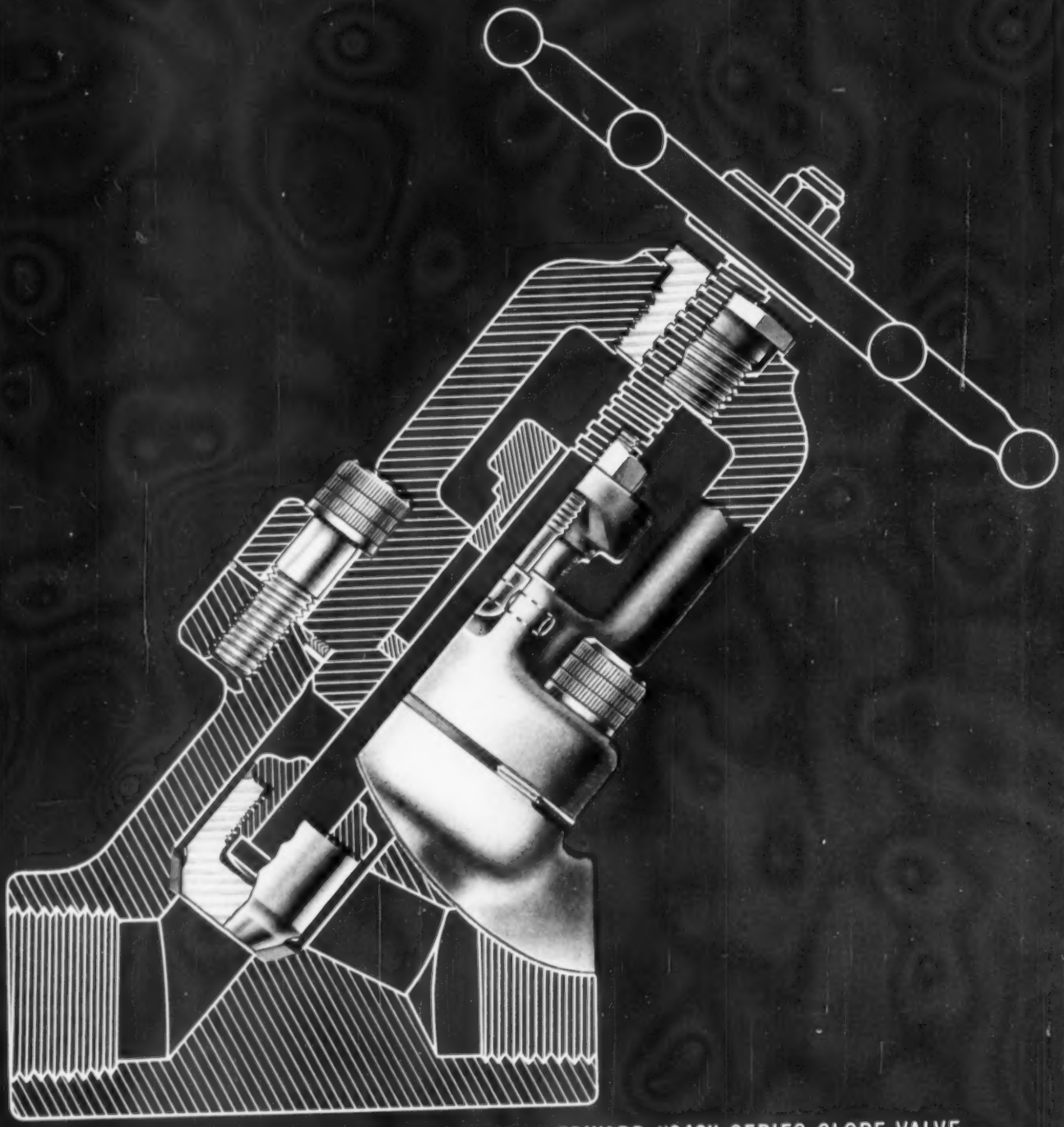
You can get standard operating temperatures from the cheaper fuels if combustion temperature is high enough. Peat, bagasse or even wood can be used successfully. The Ljungstrom Air Preheater can increase combustion temperature by as much as 300 by recovering heat from the exhaust gas. This reclaimed heat would otherwise go up the stack. All it costs is the price of the preheater—and the Ljungstrom can save enough on fuel to pay for itself in approximately two years.

You can be sure of maximum heat recovery because the Ljungstrom's exclusive rotary heat transfer element picks up the heat from the exhaust and puts it back into the combustion air without passing it through partitions or tube walls. Package design gives you all the advantages and economies of the Ljungstrom in a compact, preassembled unit. The Package Ljungstrom is available in vertical or horizontal models that are readily adaptable to any plant arrangement.

For further information, write today for the free 14-page Package Ljungstrom manual.

THE AIR PREHEATER CORPORATION

60 East 42nd Street, New York 17, N. Y.



EDWARD "848" SERIES GLOBE VALVE
(ANGLE TYPE ALSO AVAILABLE)

What's New from Edward Valves

New Products . . . Problems and Solutions. . . Information on Steel Valves from Edward, Long-Time Leader in the Field!

Major Improvements at No Extra Cost Mark
New "848" Series Forged Steel Stop Valves

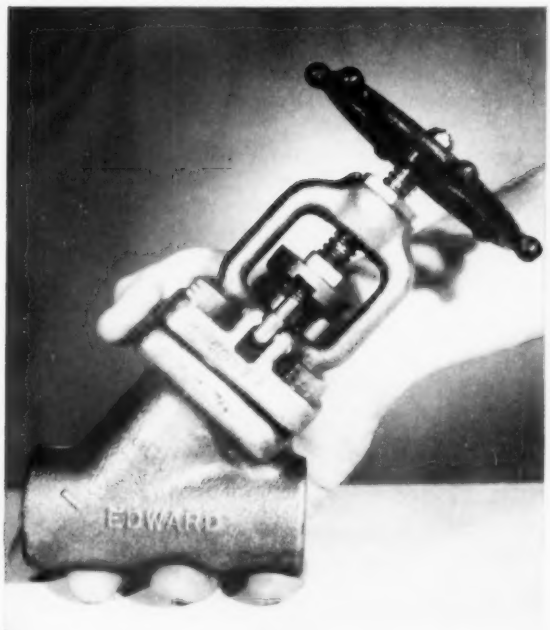
In an industry where any change in design is "news," Edward is proud to introduce a new line of 600-lb forged steel stop valves with so many major design improvements *at no increase in cost.* These Rockwell-built Edward valves are suitable for air, water, oil and other hydrocarbons, anhydrous ammonia and other gases, steam and other non-corrosive fluids.

NEW MATERIALS USED THROUGHOUT

Besides tough drop-forged steel, which is the basis of these valves, Edward introduces such innovations as stainless steel gland bolts, an aluminum-bronze yoke bushing, solid disk of chromium-cobalt-tungsten stainless steel, spiral wound gasket of stainless steel and asbestos, and special alloy cap screws linking body and bonnet.

NEW IMPROVED BODY-BONNET JOINT

Four molybdenum alloy cap screws secure bonnet to valve body. These compact, high-strength cap screws require less space than ordinary nuts and bolts, can be handled with one hand, and deliver maximum compressive force with minimum tightening torque. A new spiral wound gasket, consisting of some 20 turns of stainless steel and asbestos, provides controlled compression not possible with ordinary flat gaskets. Because this spiral wound gasket is free to expand and contract as needed, it "takes up the slack," maintains a leak-proof seal between body and bonnet.



NEW SOLID DISK OF SPECIAL ALLOY

Disk is made of chromium-cobalt-tungsten stainless steel. This new alloy has added resistance to erosion, holds its hardness better under high temperatures than other disk materials. Disk is lock-welded to disk nut, eliminating wobble and chatter—especially important when valve is called upon for throttling duty.

INTEGRAL STELLITE SEAT FOR LONG LIFE

Valve seat is Stellite—a harder, longer-wearing material with excellent resistance to corrosion, erosion and temperature. Seat is integrally welded to body.

"848" SERIES ROCKWELL-BUILT EDWARD VALVES are available in ¼", ⅜", ½", ¾" and 1" sizes. They are rated at 600 psi—at 910F in carbon steel and at 1030F in chrome-molybdenum steel. Globe or angle types, with screwed or welding ends. Write for facts on performance . . . price . . . and delivery. Address *Edward Valves, Inc., 1206 West 145th Street, East Chicago, Indiana.* (Subsidiary of Rockwell Manufacturing Company.) Represented in Canada by Lytle Engineering Specialties, Ltd., 360 Notre Dame St. W., Montreal 1, Quebec.

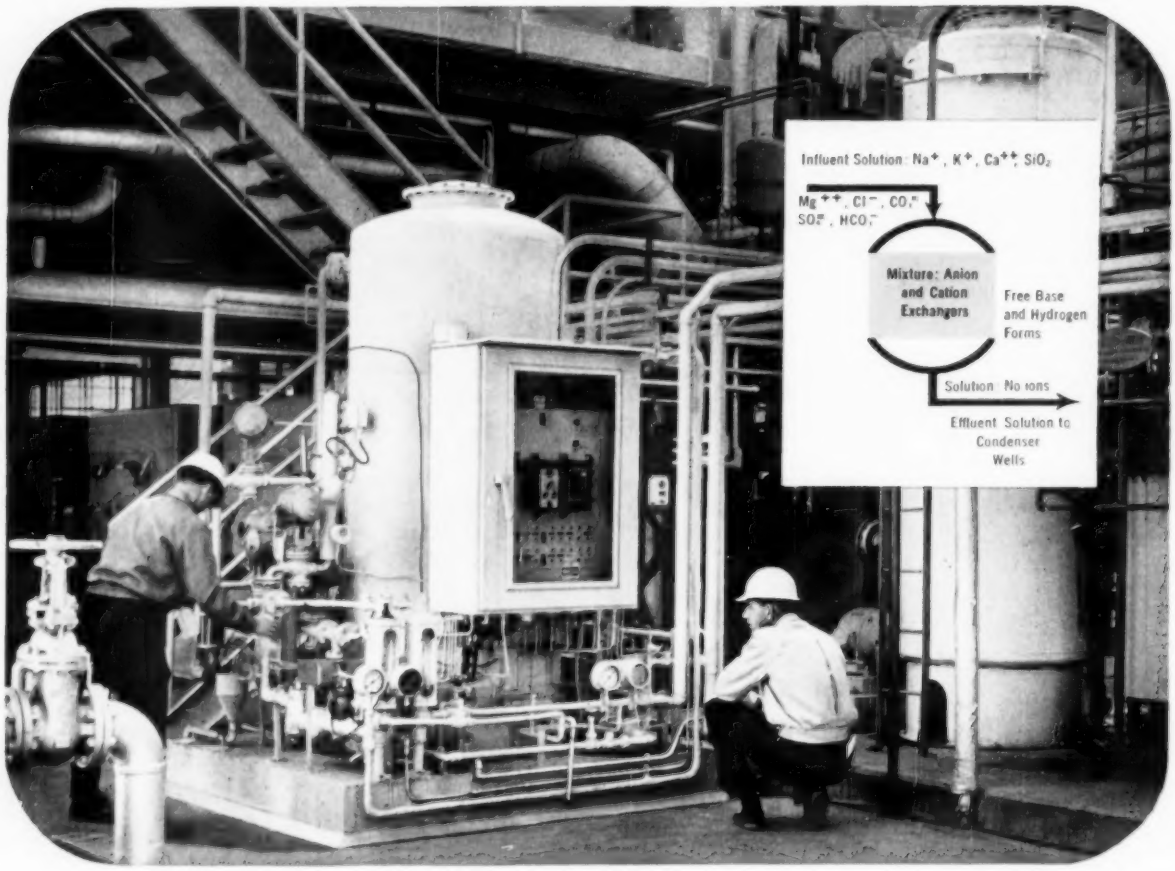
EDWARD STEEL VALVES

another fine product by

ROCKWELL

Catalog 14 contains full data on the complete Edward line of forged and cast steel valves from ¼" to 18", in globe and angle stop, gate, non-return, check, blow-off, stop-check, relief, hydraulic, instrument, gage and special designs; for pressure up to 10,000 lbs; with pressure-seal, bolted, union or welded bonnets, with screwed, welding or flanged ends.

ION EXCHANGE RESINS protect ultra-modern power plant


Influent Solution: Na^+, K^+, Ca^{++}, SiO_2
Mg^{++}, Cl^-, $CO_3^=$
$SO_4^=$, HCO_3^-
Mixture: Anion and Cation Exchangers
Free Base and Hydrogen Forms
Solution: No ions
Effluent Solution to Condenser Wells

Low 0.001 ppm Silica Content of AMBERLITE-Treated Water Keeps Powerplant Turbines Clean as New for Five Full Years

A continuous supply of water with a silica content of 0.001 ppm and below has practically eliminated causes of maintenance downtime on boiler and turbines at Louisiana Power & Light Company, Ninemile Point steam electric generating station near Westwego, Louisiana.

When a turbine was opened for the first time in five years of operation, all blading was completely clean. There were no signs whatever of deposits. No boiler or superheater tubes have been lost and iron oxide deposits on tubes are described as "very low".

Using a MONOBED mixed bed of AMBERLITE IR-120 cation exchange resin and AMBERLITE IRA-401 anion exchange resin, LP&L supplies water with less than 0.1 ppm total solids content to generating equipment at its ultra-modern Ninemile Point Steam Electric Station. The unit is rated at 14,600 gallons with an influent of 380-mmho and effluent quality averaging 0.4 mmho.

LP&L reports results are better than an evaporator would give with the same water supply. The pH runs approximately 6.8 to 7.0.

Regeneration of the MONOBED unit is completely automatic. A master timer regulates the process. Control is much closer than would be possible under manual operation, resulting in substantial saving of chemicals and water.

In any ion exchange system, effluent quality is dependent upon not only influent composition but upon unit design and operating technique. Consult your engineering company experienced in water treatment for full information on how AMBERLITE ion exchange resins may help to solve your needs for deionized, softened, dealkalized or deacidified water. Write for your copy of our booklet "If You Use Water".

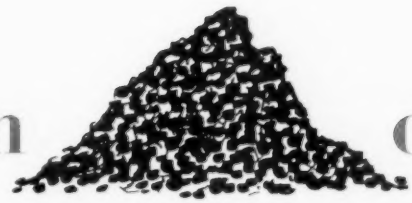
AMBERLITE and MONOBED are trademarks, Reg. U.S. Pat. Off. and in principal foreign countries.

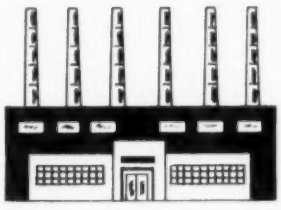
Chemicals for Industry

ROHM & HAAS COMPANY

THE RESINOUS PRODUCTS DIVISION

Washington Square, Philadelphia 5, Pa.

modern  coals for

modern  plants mean

lower steam costs

Valley Camp Quality Coals are completely prepared in modern preparation plants for burning in the very latest stoker equipment . . . a combination sure to result in lower steam costs for you.

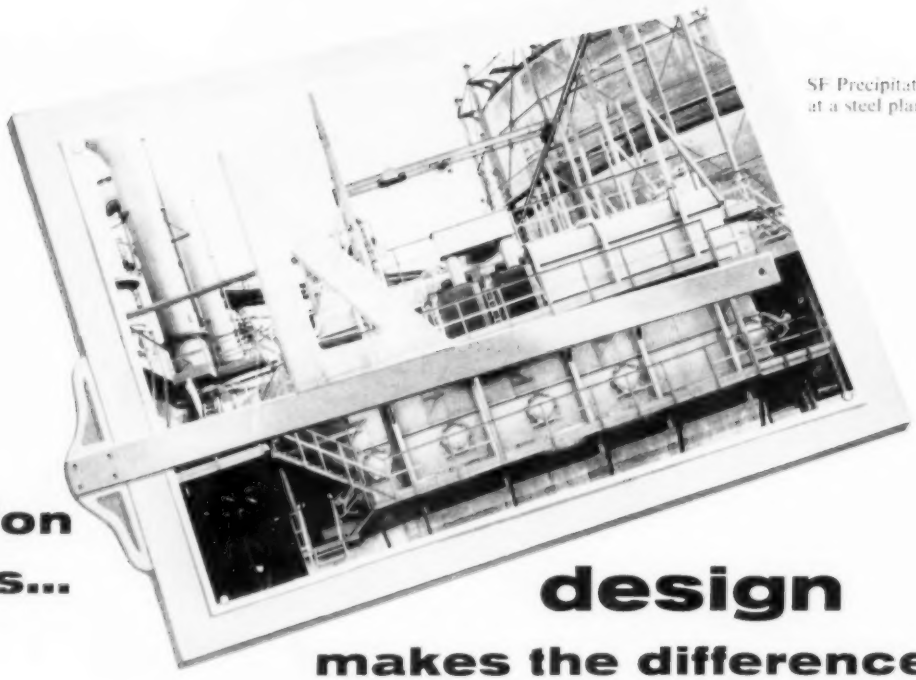
Our combustion engineering service is available at your request.

THE VALLEY CAMP COAL COMPANY

Western Reserve Building • Cleveland 13, Ohio

SUBSIDIARIES —
Great Lakes Coal & Dock Co., Milwaukee, Wis. • Great Lakes Coal & Dock Co., St. Paul, Minn. • Fort William Coal Dock Co., Ltd., Fort William, Ont. • The Valley Camp Coal Co. of Canada Ltd., Toronto, Ont. • Kelley's Creek & Northwestern Railroad Co. • Kelley's Creek Barge Line Inc. • Pennsylvania & West Virginia Supply Corp.

SALES OFFICES —
Philadelphia • Baltimore • Buffalo • Pittsburgh • Wheeling • Cleveland • St. Paul • Cincinnati • New York • Milwaukee • Superior, Wis. • Fort William, Ont. • Toronto, Ont.



SF Precipitator at a steel plant.

In Dust Collection Systems... design makes the difference

Higher efficiency of Buell 'SF' Electric Precipitators is the result of exclusive engineering features. For example, Buell's *Spiralectrodes* emit 50% to 100% more electrons than other types . . . and *maintain* their efficiency. Positive gas flow control through adjustable baffles prevents scouring and eddying. And Buell's Unique Continuous Cycle Rapping practically eliminates "puffing".

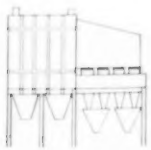
BUELL CYCLONES

Lower installation cost of Buell's time-proved simplified design makes erection faster and easier. Spiralectrodes, for example, are self-tensioning, require no weights. Flexibility of power supply means easier installation, operating safety.

"SF" ELECTRIC PRECIPITATORS

Lower maintenance cost is the result of many details of superior design. And sectionalized design permits shutting down part of a unit without interrupting service in the rest of the unit.

Get full information: write for a copy of "Buell SF Electric Precipitators", a 22-page booklet. Write to Dept. 70-C, Buell Engineering Co., Inc., 123 William Street, New York 38, N. Y.



PRECIPITATOR-CYCLONE COMBINATIONS

buell®

Experts at delivering Extra Efficiency in **DUST COLLECTION SYSTEMS**

COMBUSTION

Editorial

Macroscopic and Microscopic

In these days of space flight and fusion reactions the exponential notation that physicists use for physical quantities has become more widely known. Dealing in large numbers, for example, one of the nearest stars, Sirius, is 5×10^{13} miles away. By contrast, there is the electron volt, which has a value of 1.60607×10^{-12} erg.

What is probably not so commonly realized is that the 500-mw single boiler-turbine-generator unit involves quantities that in numerical value rival those of the astrophysicists and the specialists in atomic physics. The heat input per day to a 500-mw boiler is on the order of 11×10^{10} Btu. At the other extreme, impurities in boiler feedwater and steam may be measured in fractional parts per billion, or 10^{-9}. Purely as an intellectual curiosity and without any physical meaning, the ratio of these two extreme quantities in a 500-mw unit is 11×10^{19}.

There are many critics, particularly in the field of engineering education, who feel that the steam power plant has much less challenge for mechanical and electrical engineers than in past years. One of the oft-repeated arguments of these critics is there is little creative opportunity in extrapolating a larger steam plant from a smaller one. Enlarge the boiler, turbine, piping, pumps, generator and condenser and that is all there is to it, so the argument goes.

Had steam conditions remained at the level of forty years ago, then a 500-mw unit could be projected merely by proportionate enlargement of a 50-mw unit. It could be built, it could be operated and it might even be designed by a technician who lacked the desire to create anything better. Yet who would purchase and install a 500-mw unit operating at 400 psig, 600 F? The answer is that no public utility could afford to install a unit whose thermal efficiency is so low and cost of operation so high.

What happens when a 500-mw unit is designed for advanced steam conditions? Paradoxically, as the title of this editorial suggests, large size requires both gross and microscopic measurements. In effect, the larger the unit, the greater the diversity in measurements.

At the one extreme the coal input to the station may be measured as a trainload of 70-ton coal cars per day. Assuming 20 per cent ash in the coal, the amount of germanium that might be recovered per day from the ash would be on the order of a few milligrams. Or take steam flow, the measurement of a flow of 3,750,000 lb of primary steam per hour must be visualized with respect to the simultaneous measurement of steam impurities in parts per billion.

This great diversity in measured physical quantities stems from the combined requirements of large size and advanced steam conditions. Physical properties of metals are approaching their upper limits under these conditions, and therefore extreme precaution must be taken not to exceed these limits. One way of exercising precaution is through extremely precise measurements.

In so many words, the 500-mw boiler-turbine-generator unit of today and the 1000-mw unit of tomorrow demand the best in accurate measurement and engineering knowhow. In this sense, the physicist has no monopoly on large numbers and precise measurements. The combination of size and advanced steam conditions offers a challenge to engineering design that cannot be met by extrapolation of past practice. The steam power plant of the future will continue to be a place where progress is dependent upon engineering excellence.

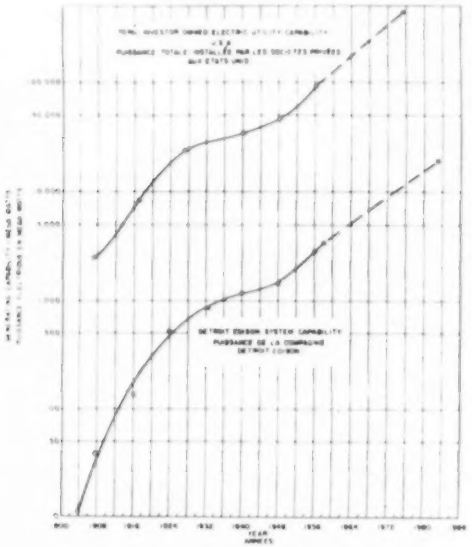


Fig. 1—Electric generating capability growth

The electric generating industry has a reputation for holding the line on power costs against increasing fuel, labor and capital rises. This reputation owes its being to the willingness on the part of the industry to challenge the currently best in performance or design. Here is a first rate report on how one organization in the field makes its challenges.

By GEORGE A. PORTER† and DICK E. HART††

The Detroit Edison Company

Economic Trends in the Generation of Electric

THE growth of electric demand in the Detroit Edison system, during the past quarter century, has been typical for large thermal systems on the North American Continent. Whereas the demand and system capability were approximately 450 mw and 870 mw, respectively, in 1933, it is expected that the system demand will be 2940 mw in 1958 with a capability of 3420 mw. If the electric demand continues to grow in the next 25 years as it has in the 25 years which are now history, the system demand in 1983 will be approximately 17,200 mw, with an expected system capability of 19,000 mw. This impressive demand growth is shown graphically in Fig. 1, and illustrates the parallelism between the growth of the investor-owned electric generating industry in the United States and that of the Detroit Edison Company.

The impact of this growth is to emphasize the need for long range planning that will achieve, annually, the lowest possible electric generation cost. Small economies are greatly magnified by the compounding of unit size. For example, in the year 1958, the newest generating unit, 325,000 kw, in the system will accrue a total sum of $240,000 in the course of a year, if a saving of 0.1 mill per kwhr is achieved. This is equivalent to the carrying charges on an investment of $1,900,000. In 1983, a saving of 0.1 mill per kwhr will amount to approximately $1,060,000 for a single unit, or an equivalent investment of $8,480,000.

It has always been the aim of the electric power industry to produce and sell electricity at the lowest possible cost per kilowatt hour consistent with reliable service. How well this has been done over these 25 years can quickly be demonstrated by referring to any cost index relating commodity and power costs. The compounding trend in construction, fuel and labor costs, if not offset by bold economies, will result in the same characteristic rise in electric energy cost as has been experienced for other commodities.

Historic cost trends, when projected into the future, forecast unbelievable cost levels within several decades. Fuel in 1983 may cost 2.1 times today's price, or 65 cents per 10^6 Btu; construction costs to reproduce today's $150 per kw power plant may be $510 per kw; and labor costs which average $2.84 per hour today may be $11.40 per hr. Curves illustrating these cost trends, are shown in Fig. 2. System growth may provide some offset of these inflationary trends since the use of progressively larger units in a growing system effect lower construction, operation and fuel costs per unit of generation. This effect cannot be maintained indefinitely, however. Consequently, we have reached a point in time when greater economy in construction methods, improved utilization of fuel, and careful assignment of operating labor is of paramount importance if this tremendous cost momentum is to be retarded.

The purpose of this paper will be two-fold. First, there will be a discussion of economic studies which have provided immediate reductions in the construction, fuel and labor components of generating costs and, consequently, have been applied to the most recent capacity additions at our River Rouge and St. Clair Power Plants. Second, economic studies will be discussed which are in the category of future development, since either the art of power generation has not progressed to the point of practical utilization of the systems studied,

† Vice president in charge of engineering, construction and operations.
†† Special studies engineer, Planning and Project Engineering Dept.
* Presented before the World Power Conference, Canadian Sectional Meeting, Montreal, Canada, Sept. 7-11, 1958.

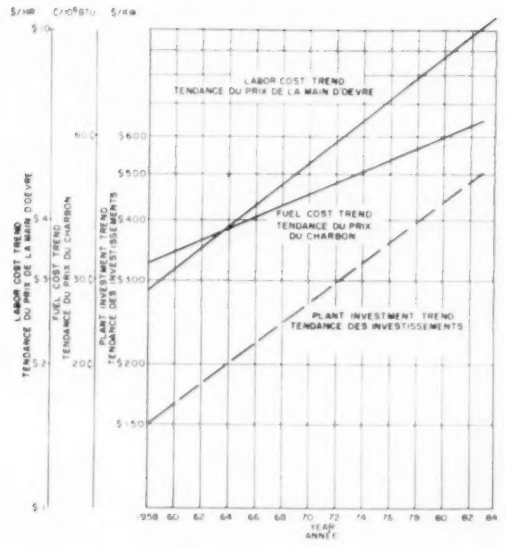


Fig. 2—Projected cost trends for investment labor and fuel for the Detroit Edison Co.

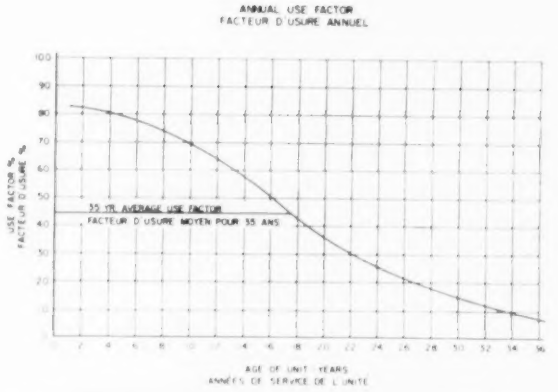

ANNUAL USE FACTOR
FACTEUR D'USURE ANNUEL
USE FACTOR %
FACTEUR D'USURE %
35 YR. AVERAGE USE FACTOR
FACTEUR D'USURE MOYEN POUR 35 ANS
AGE OF UNIT, YEARS
ANNÉES DE SERVICE DE L'UNITE

Fig. 3—Projected use factor for turbine generator operating with single boiler

Energy in the Detroit Edison System*

or the economic factors are not sufficiently powerful to justify the present adoption of the systems.

Economic Studies Affecting Recent Capacity

Economy of Larger Unit Size. It is well established that size increments in generating equipment are generally obtained at cost increments considerably lower than the equipment base cost. A recent comparison of costs for the four-unit St. Clair Plant completed in 1954 with a completed three-unit plant at the River Rouge site will illustrate the major effect of large unit design companies.

If the St. Clair unit size, 156,250 kw, and steam conditions, 1800 psig −1000 F −1000 F reheat, were repeated at the River Rouge Plant considerable additional investment cost would have resulted. The cost of the four-unit St. Clair Plant (660 mw) escalated to April 1958, the completion date for the River Rouge three-unit plant, would have been $180.00 per kw. The cost of the River Rouge Plant (875 mw), however, was $135 per kw. This difference in first cost results primarily from:

(a) Cost reduction attributable to unit size effect—$33 per kw.

(b) Cost reduction attributable to more economical design—$12 per kw.

Reduction in plant cost resulting from larger generating units can be readily appreciated by noting its effect upon the main power station building cost. This is graphically illustrated by the fact that the River Rouge turbine room is only 8 per cent larger in volume than St. Clair, but the capacity housed at River Rouge has increased by 33 per cent. Other cost factors such as site development, coal handling, engineering and design, miscellaneous buildings, and dock costs do not increase directly with size.

Although cost reductions attributable to design concepts developed at predecessor plants when applied to a new plant are not stimulated by size alone, such economies, when applied, are emphasized by virtue of larger size. Numerous design savings were made at our River Rouge Plant as a result of design experience gained from the preceding plant, St. Clair. The savings made according to major plant cost categories were:

Main Power Station Building	
Elimination of sub-basement, metal walls replacing brick walls, higher stressed building steel, lighting, etc.	$3,600,000
Miscellaneous Station Building	
Reduction in warehousing, Screen house superstructure, etc.	$ 600,000
Boiler Plant Equipment	
Constant speed instead of variable speed fans, foreign manufacturer's pipe, increased velocities in pipe, etc.	$ 660,000
Coal Handling System	
Use of mobile equipment instead of stationary conveyor	$3,200,000
Turbine-generator Plant	
Water treatment	$ 140,000
Station Transmission	
Air-cooled rather than oil-cooled transformer	$ 100,000
Total design economy	$8,300,000

TABLE I—COST COMPARISON OF STEAM CONDITIONS IN TERMS OF INCREMENT COSTS ABOVE THE COSTS FOR 1800 PSIG—1000 F REHEAT 260,000 KW UNIT SIZE

	1800 Psig 1050 F 1000 F Reheat	1800 Psig 1050 F 1050 F Reheat	2000 Psig 1050 F 1000 F Reheat	2000 Psig 1050 F 1050 F Reheat
Steam generator	$126,000	$280,000	$216,000	$370,000
Turbine generator	124,000	251,500	170,000	295,100
Piping	20,000	30,000	30,000	40,000
Feedwater heaters	0	3,800	10,000	10,000
Pumps and drives	0	0	15,000	15,000
Condensers	−5,000	−10,000	−10,000	−16,000
Total	$275,000	$547,700	$361,000	$744,100
Total indirect, 25%	70,000	138,300	115,000	185,900
Total increment cost	$345,000	$686,000	$476,000	$930,000
Annual Saving Resulting from Reduced Heat Rate				
Uniform annual coal savings corresponding to 40c per 10⁶ Btu fuel cost and a use factor of 36 per cent	$ 35,440	$ 70,880	$ 75,360	$116,000
Pump power saving	440	880	−5,360	−5,000
Net annual saving	$ 35,000	$ 70,000	$ 70,000	$111,000
Per cent return on increment investment	10.1	10.2	12.1	12.0

The River Rouge Plant, therefore, will cost some $10 to $12 per kw less than the St. Clair Plant because of economies brought about by design changes. The considerably lower coal handling investment resulted from shorter distance for stocking and reclaiming with greater use of mobile coal moving vehicles. These economies represent better than 5 per cent of the total plant cost of St. Clair if reproduced today. Since thermal economies apparently are becoming increasingly difficult to justify, a program of continued design surveillance for future plant should produce significant economies.

However economy through largeness cannot be adopted without proper consideration of the disadvantages which are inherent in largeness. The operating disadvantages can be reduced to economic considerations, although at times such economic evaluation is not too rigorous.

In determining unit size, consideration should be given to the relationship between new unit size and the system capacity and spinning reserve requirement. Examination of the proportional size of previous units on the Detroit Edison system over the past 30 years indicated that, when a new, larger size has been introduced, it has generally been between 10 per cent and 15 per cent of the system demand. The River Rouge No. 1, 260 mw unit, was about 10 per cent of the system demand in 1956, the year of its installation, and for most of its life will not be larger than the spinning reserve required for weather forecasting error.

The question of additional carrying charges that may be incurred with the larger size due to the greater length of time required for system load growth to utilize the full capacity of the unit was also considered. It is difficult to obtain a definite answer to this question, since the timing of new units does not depend entirely upon load growth, but involves other factors such as maintenance time, provision for unforeseen growth, possible margins for rebuilding old plants, power available for purchase from interconnections, and others. A theoretical study on the assumption of steady uniform growth with units of the proper size coming in just as needed indicates a possible saving of approximately 1.5 per cent of the annual carrying charges on the larger unit. This, however, is a small amount in terms of the other investment economies cited, and can be overcome by staggering construction in an interconnected pool.

It might be inferred that a larger unit would require somewhat more system reserve to provide against its outage than would be required for a smaller unit. While this is the case for isolated systems, it is of less importance when the system is part of a large power pool. Normally, reserve is considered in terms of a percentage of system load. In determining the reserve required such factors as maintenance, summer peaks and diversity may be important considerations. No additional investment is, therefore, anticipated for the larger unit in relationship to system reserve over the long run.

Another factor that must be considered is the adverse effect that larger units might have on the transmission system. This concerns possible excess transmission costs, heavy concentration of loading at transmission terminal stations and increase in short circuit duty requiring larger circuit breakers or means for moderating this effect. These anticipated problems have been effectively solved by the careful coordination of line sizes, the number of lines per generator section, and by dispersion of the line terminations among several stations. Generator sections tied together at the plant through reactors have also aided as a solution to the transmission problems. No disproportionate effect, therefore, in transmission cost was encountered with the larger unit.

The conclusion reached, therefore, is that there is appreciable economy in installation cost attributable to size which is not offset by other considerations. Units as large as 340 mw gross are being installed in the Detroit Edison system and still larger units are being proposed by equipment manufacturers. It may be that units as large as 500 mw will be advantageous in the Detroit Edison system by 1965, particularly if such size increases result in construction cost economies approaching the 18 per cent achieved at the River Rouge Power Plant, although present trends indicate that above the 350 mw unit size, the reduction in installed cost per kw will diminish considerably.

Economy of Improved Steam Pressure and Temperature

Carnot, many years ago, established the fact that with the relatively fixed level of the ambient at any particular location, the most effective improvement to the cycle efficiency for thermal plants is brought about by increasing the cycle primary temperature. This incentive has led to the well established trend of 50 F increase every four to five years in primary steam temperature and appears to provide a realistic extrapolation to the future assuming metallurgical advances are continued. With each major generating addition to our system, efforts have been made to establish the most economical set of primary steam conditions and this invariably has resulted in an improvement over previous generation.

TABLE II—COST COMPARISON FOR INCREASING THE PREHEAT TEMPERATURE TO 1050 F FROM 1000 F REFERENCE CONDITION 2400 PSIG—1050 F—1000 F REHEAT 325,000 KW UNIT SIZE

	Investment Increment
Turbine generator	$264,100
Steam generator	195,000
Piping	29,800
Condenser	−14,000
Heaters 1 through 7	−9,955
Total direct costs	$464,945
General items including contingencies, escalation, interest, etc (20%)	$ 92,989
Total increment investment	$557,934
Annual savings in fuel and pumping power	$ 31,950
Return on increment investment	5.7%

In an effort to determine the optimum steam pressure and temperature for the initial two-unit installation at our River Rouge Power Plant, the steam conditions described in Table I were considered. Each of these conditions was compared to 1800 psig – 1000 F – 1000 F reheat which were adopted at the predecessor plant, St. Clair. The St. Clair Power Plant, placed in operation in 1954, was the first plant in our Company to incorporate reheat, which, as in other utilities, was readily justified.

The net fuel savings for the higher steam temperatures and pressures do not provide a high return on the required increment investment in any case, and particularly for the two cases at 1800 psig for which the return is less than 12.0 per cent, the required return to meet the carrying charges on plant equipment with an economic life of 35 years. Although the return for the 2000 psig conditions was not overly attractive, it was decided to make an advance in steam conditions in view of probable higher fuel costs than assumed in the study and the desire to make a progressive step in power plant design. Consequently, 2000 psig – 1050 F – 1000 F reheat was selected. A reheat temperature of 1000 F rather than 1050 F was used, expecting that the higher temperature would involve metallurgical problems which might result in increased maintenance costs with no proportionate gain.

A later review of costs related to a 2400 psig throttle pressure proved that the 400 psig increase in pressure offered sufficient fuel economy to provide a 17.0 per cent return on increment investment. This was attributable to more favorable investment costs. As a result 2400 psig has been adopted for the third unit at River Rouge which went into operation this Spring, and for Units Nos. 5 and 6 at St. Clair, scheduled for operation in 1959 and 1960, respectively.

Repeated studies of reheat temperatures equal to superheater outlet temperatures fail to show sufficient economy. Table II provides an explanation of the poor economy in reheat temperatures which equal primary temperatures.

The specific investment in turbine-generator and steam-generator are disproportionately high when compared with the thermal economy provided. This, undoubtedly, results from the increased use of austenitic materials at the 1050 F reheat temperature in the steam-generator, the more involved reheat turbine structure and more expensive materials in reheat turbine inlet valves and inlet bowl.

A number of other power companies have employed reheat temperatures equal to superheater outlet temperatures for subcritical installations. Justification may possibly have been made on basis of higher fuel cost or-

TABLE III—COST COMPARISON OF TURBINE TYPES OF 250 MW CAPABILITY

	Investment Differences		
	Cross-Compound Double Flow CCDF	Cross-Compound Single-Flow CCSF	Tandem-Compound Triple Flow TCTF
Turbine-generator	+ $120,000	+ $17,000	0
Steam generator	0	+ $215,000	+ $215,000
Auxiliaries (heaters & pumps)	0	+ $57,000	+ $57,000
Building	+ $260,000	+ $67,000	0
Total plant compared to TCTF	+ $408,000	+ $111,000	0
Heat rate difference, capitalized fuel savings	0	+ $509,000	+ $623,000
Investment adjusted for heat rate	+ $408,000	+ $623,000	+ $623,000
Net investment adjusted for heat rate, compared to CCDF	0	+ $215,000	+ $215,000

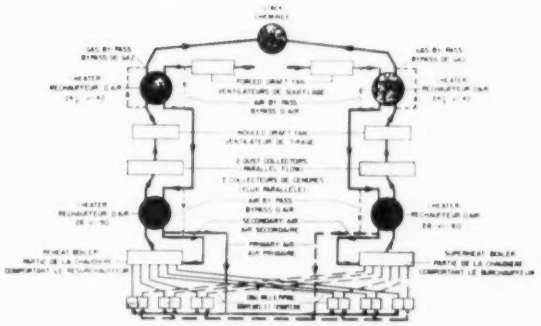


Fig. 4—Gas-air circuit diagram, River Rouge 3

cost trends, greater use factors, the desire to continually improve the efficiency of generation, or other factors which vary between power systems.

Value of Heat Rate Improvement

The most critical item in any economic study involving thermal improvement is a realistic assignment of an equivalent, uniform annual fuel saving provided by 1 Btu per kwhr improvement in plant heat rate. The computation of this unit of fuel saving involves a careful projection of the (a) plant use factor and (b) fuel cost trend. The plant use factor, although estimated from the history of previous units, must be related to a future system condition, which will show less rapid reduction in system heat rate than in the past, and to future reserve policy. Also, nuclear plants, which may have a very low energy cost and, therefore, receive preferential loading, may have an important influence in future unit loading. A projected Use Factor Curve which attempts to anticipate such circumstances is shown in Fig. 3. The average life-time use factor, derived from this curve, is approximately 45 per cent. Since the plant use factor has a very important effect in economic studies involving thermal improvements for fossil fuel plants, great care should be exercised in its determination.

One important factor, often overlooked, in determining the equivalent, uniform fuel saving resulting from a thermal economy is the time-value of money. Obviously, savings made early in the economic life of a piece of equipment are more valuable than savings made at a later date, and may be simply illustrated by the increased earning power of the earlier savings on the money market. Furthermore, the use factor of a unit in our thermal system tends to decrease with unit age resulting in a lower generation base on which to make savings as the unit becomes older. This diminishing saving together with the time-value of money is best accommodated by the method of "present-worth" of all annual savings.

Economic Selection of Generating Unit Type

Single-shaft generating units are lower in price than two-shaft, cross-compound generating units; consequently, in sizes up to 200 mw the single-shaft, or tandem-compound units, are generally an economic selection for exhaust pressures of 1.5 in. of Hg or higher. However, in geographical areas where condensing water is sufficiently cool to produce pressures of 0.5 to 1.0 in. hg absolute at the turbine exhaust flange over considerable

periods in an operating year, the exhaust annulus of the last-stage wheels on 3600 rpm tandem-compound units is insufficient to accommodate the large volumetric flows without abnormal last-stage energy losses. The 1800 rpm, multiple-exhaust, 1-p turbine on cross-compound units will improve the turbine-generator heat rate by approximately 120 Btu per kwhr for units of 260 mw capacity.

In an effort to determine the most economical generating unit type for our River Rouge Plant, three turbine types were studied (a) cross-compound double-flow (b) a similar type cross-compound unit but with single flow exhaust (c) tandem-compound triple flow exhaust. The cross-compound single-flow unit was a new development at the time of the study, being recommended for consideration on the basis that it offered a price comparable to the single-shaft unit and a heat rate which was slightly better. Table III shows the cost relationship between the three types.

The cost items shown in the above tabulation reflect the basic difference in turbine price, the added cost of steam generators for the units having higher steam rates, the added cost of auxiliaries resulting from the higher steam rates and the effect of the turbine-generator dimensions on the size of the turbine room. Since the steam rate differences were in the order of 2 per cent, a question arose as to the real price differences that would be attached to such small changes. Careful inquiries were made, however, and the cost data shown represent the price differences provided by equipment manufacturers.

The study indicated that the appreciably better heat rate with associated fuel savings for the cross-compound double-flow unit completely offset its higher investment cost. The rather large capitalized fuel saving is attributable to the low exhaust losses of an 1800-rpm last-stage blading when operating at exhaust flange pressures between 0.5 in. and 1.0 in. Hg absolute.

Another inherent advantage attached to the cross-compound unit is that the 3600-rpm generator is approximately 50 to 60 per cent of the rating of the generator employed by the 3600-rpm tandem-compound unit. This permits conventional hydrogen cooling on the cross-compound unit and also reduces the size of the 3600-rpm field, precluding the possible operating hazards of larger generator sizes.

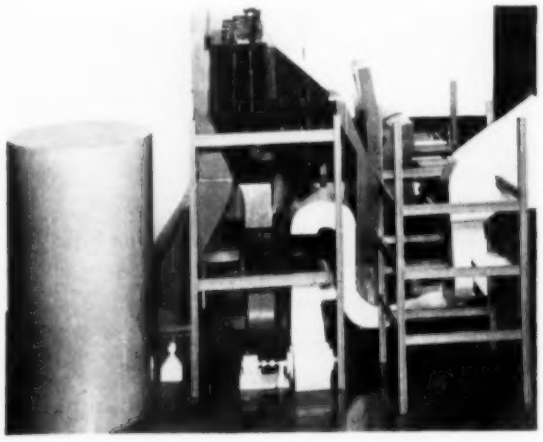


Fig. 5—Model of series air preheater arrangement

Concurrent with our study on turbine-generator type, one large manufacturer and several utilities conducted similar studies. From these studies it can be concluded that for turbine-generator units above 200 mw in rating and operating below 1.5 in. Hg absolute at the turbine exhaust flange, the cross-compound double-flow unit is the most economical turbine type.

Reduced Steam-generator Exit Gas Temperature Studies

The second major thermal loss in the conventional power generation cycle burning fossil fuels is the sensible heat loss in the products of combustion entering the steam-generator stack. The reduction of the exit gas temperature, and as a direct result the thermal loss, is limited, for coal-fired steam-generators, by the sulfur and moisture content of the coal. Practical design has restricted the minimum full-load, exit-gas temperature to a range of 250 F to 300 F depending on the analysis of the coal. This restriction arises from operating problems such as corrosion, air heater plugging and flue dust removal difficulties. One approach to reduced thermal loss is to divide the air-heating surface into two parts, placing the normal surface ahead of the flue dust collector and additional surface following the flue dust collector.

In the course of a study on such a series air-preheater arrangement it was determined that (a) gas at a temperature approximately 235 F is probably the most corrosive; therefore, corrosion should not increase appreciably with a further reduction in temperature; (b) corrosion and air heater plugging should decrease with decreased dust loading for a fuel of a given sulfur content. Based on these determinations, a study was conducted using a series air-preheater arrangement which would result in a 200 F full load, exit-gas temperature.

Operating conditions, developed at the outset of the study, required that the design should provide:

(1) The hot-gas air preheater should operate in a temperature range to preclude or minimize plugging and the temperature should be conservative for flue-dust collector design.

(2) The cold-gas air preheater should be arranged to permit frequent removal from service for washing, and the outage should not affect steam-generator availability or capacity.

(3) A reasonable steam-generator efficiency should be maintained during cold-gas air preheater outages.

A gas-air circuit diagram for River Rouge No. 3 steam-generator is shown in Fig. 4. A view of a model showing the physical arrangement of the air preheaters and associated duct work is given in Fig. 5.

The study indicated that a steam-generator efficiency improvement of approximately 1½ per cent was possible. Considering fan power requirements and other operating costs, the $70,000 net annual fuel saving, resulting from the lower-exit gas temperature, provided an attractive return on the required investment. Considerations, intangible to cost assignment but appearing favorable, were (a) the arrangement represented a major forward step in steam-generation efficiency; (b) continuity of service might even be improved over the conventional air preheater arrangement since the hot-gas air-preheater

would operate in an apparently trouble-free temperature range and the cold-gas air preheater could be removed from service without adversely affecting availability or capacity, and; (c) the flue dust collector would operate at a temperature which would minimize corrosion and flue-dust removal problems. These factors led to the installation of the series air-preheater arrangement for Unit No. 3 at the River Rouge Plant.

Economy Studies for Future Improvement

Feedwater Cycle Improvement. The literature showing approximate improvement for the regenerative feedwater cycle for total feedwater temperature rise, number of feedwater heaters, distribution of feedwater heaters, etc, is quite voluminous. However, cycle improvements in the amounts of 0.25 to 0.50 per cent often can be discovered by careful cycle computation. The incentive to make such small improvements stems from the fact that a 0.25 per cent improvement in cycle efficiency will justify an investment of $100,000 for a unit of 325 mw capacity.

Computation of numerous feedwater cycle arrangements are not only tedious, but require extended calculation time. With the pressure of more imperative engineering work oftentimes these apparently unimportant, but rewarding, studies must be set aside. In an attempt to foreshorten computation time in such studies, but not sacrificing accuracy, a digital computer was employed as early as 1954 by our engineering groups.

The use of the digital computer is contemplated for all future station cycle work which requires more than 15 repetitive heat balances. Since computer programs have been developed for several of our latest units, future cycles, if not changed radically, can be analyzed by small changes in programming, and, therefore, provide considerable economy in computation time. Concurrently with this explicit programming of individual units we have been conducting a study which may produce a so-called "generalized" program. Such a program, when available, will again greatly foreshorten cycle computation time and should be of use to other utilities.

Advanced Pressure and Temperatures

We are now in the process of completing a thorough study of a supercritical steam pressure cycle employing 3500 psig-1050 F-1000 F reheat. Previously, a rather brief study was conducted in the Spring of 1956, which led to the general conclusion that the supercritical pressure cycle was not economical for generation in our system. Incremental investments referred to 2400 psig-1050 F-1000 F reheat for a 325 mw unit were developed as follows:

Steam-generator	$ 525,000
Turbine-generator	210,000
Feedwater heaters	193,000
Pumps	325,000
Demineralizer	100,000
Piping	200,000
Total direct cost	+$1,913,000
Indirect cost	500,000
Total cost	+$2,413,000
Reduced costs for condenser, canals, ash and draft equipment	−$ 325,000
Net increment investment	+$2,088,000

The improvement in plant heat rate was approximately 2¼ per cent which provides only sufficient fuel saving to justify approximately $1,100,000 of the incremental investment. This, obviously, is only 50 per cent of the actual incremental investment shown.

Also, there are distinct design and operating problems associated with supercritical pressure. Supercritical pressure, if exploited to the fullest, must be used in conjunction with relatively high steam temperatures. The significant increase in steam temperature being employed in most supercritical pressure cycles requires a careful evaluation of metallurgical problems in piping, valves, steam-generator, turbine spindle and turbine casing. There are numerous equipment developmental problems as well.

The once-through steam-generator in large capacity rating requires considerable developmental work; rather elaborate water makeup preparation systems and continuous condensate purification is required; multiple steam pipes and control valves are required creating increasing flexibility problems; and precautions must be taken at the condenser to insure no inleakage of circu

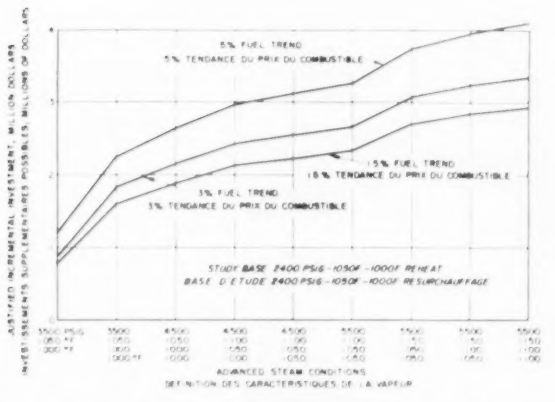

5% FUEL TREND
5% TENDANCE DU PRIX DU COMBUSTIBLE
1.5% FUEL TREND
1.5% TENDANCE DU PRIX DU COMBUSTIBLE
3% FUEL TREND
3% TENDANCE DU PRIX DU COMBUSTIBLE
STUDY BASE 2400 PSIG-1050F-1000F REHEAT
BASE D'ETUDE 2400 PSIG-1050F-1000F RESURCHAUFFAGE
ADVANCED STEAM CONDITIONS
DEFINITION DES CARACTERISTIQUES DE LA VAPEUR

Fig. 6—Incremental investment for advanced steam conditions 325,000-kw turbine generator

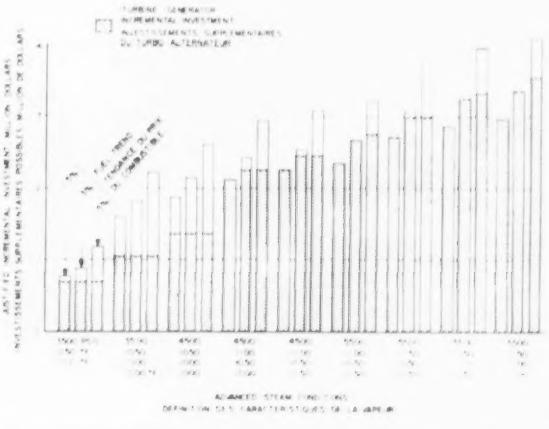


Fig. 7—Total incremental investment in advanced steam conditions (study base-2400 psig-1050–1000 F)

lating water into the condensate circuit. These problems, together with insufficient economic justification serve as a deterrent to the supercritical pressure cycle for generation in our system.

However, trend studies are made regularly to determine which of the more advanced pressure and temperature conditions show the greatest promise of economic justification. Although survey studies of this type do not consider specific investment details, careful determination of thermal economy coupled with probable long-range fuel cost and an average use factor provide sufficient information, when expressed in the form of capitalized fuel saving, to indicate the more favorable advanced steam conditions.

The incremental investment which can be supported by the fuel savings attributable to the thermal economy of advanced steam conditions is referred to as "justified investment." These justified investments for three possible long-range fuel cost trends are shown in Fig. 6. It is obvious from these trends and Fig. 7, that the justified investment by no means meets the actual investment required. The turbine-generator alone absorbs a considerable portion of the justified investment, and consequently, the required investment for steam-generator, piping, miscellaneous equipment will exceed the investment justified.

It is our conclusion that the supercritical pressure cycle with its higher steam temperatures, even though affording thermal economies of 2 to 4 per cent, is not now an economical venture and, if adopted, must be entered into on the basis of developmental generation with the hope of economical generation in the future. The most immediate incentive appears to be a radical reduction in equipment cost which can only be brought about by a major design or materials "break-through" on the part of the equipment manufacturer.

Feasibility Study of a Secondary Heat Transport Medium for the Double Reheat Cycle

With the advent of the supercritical pressure cycle, double reheat became an attractive cycle addition. But reheater system pressure drop and the increased investment in reheat intercept and stop valves were significant. It was proposed that the use of a liquid metal as a heat transport medium for double-reheat systems might overcome these disadvantages. Design and experimental data accumulated up to January 1956, the date of the study completion, indicated that the use of liquid metal would be practical in a double-reheat plant. The advantages accruing from systems using a liquid metal are:

(1) Reduction of steam pressure drop in the reheat system and a resulting thermodynamic improvement.
(2) Reduction in cost of reheat steam piping.
(3) Removal of either or both intercept and stop valves from the high temperature reheat lines.

A schematic flow diagram of the cycle employing liquid metal is shown in Fig. 8. Careful consideration was given to the design of a workable liquid metal system, and it was felt that the system evolved was practical, requiring a minimum amount of maintenance and operating attention.

The thermodynamic gain of the double-reheat system utilizing a liquid metal as a heat transport medium was 1.2 per cent when compared to the conventional double-reheat system. This thermal saving did not result in sufficient annual return to justify the investment in the liquid metal system. However, economies such as ferritic instead of austenitic materials in the liquid metal system, the combined use of a common liquid metal system for several units and a reduction in liquid metal price, all of which appear possible, would result in an improved return.

Although elimination of all valves in the steam reheat system was impossible for the system studied, further reduction in stored steam volumes may be achieved which could eliminate all valves in the reheat steam lines. This reduction in valve investment together with the higher long-range fuel costs in localities other than the Detroit Edison system might possibly justify the adoption of the liquid metals cycle.

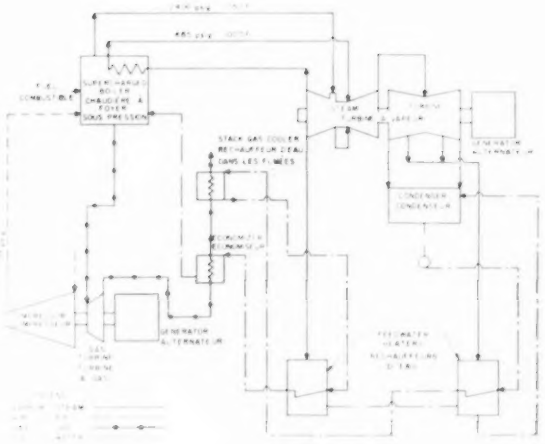
Air-Steam Binary Cycle Generating Plant

Our surveys of the air-steam binary cycle made use of a supercharged boiler, a gas-turbine compressor-generator unit and a condensing steam turbine generator. A schematic diagram is shown in Fig. 9. The gas turbine operates on the "open" cycle; that is, air is taken from the ambient and exit gases are exhausted to the ambient. Air is compressed to approximately 6 atmospheres and passed to a supercharged boiler. Fuel is used to produce combustion gases for the gas turbine and sufficient steam for the steam-turbine-generator. The gas turbine exhaust gases are directed through the steam-generator economizer and then through a stack gas cooler which, in effect, replaces a feedwater heater. For an air-steam binary cycle with a gross cycle output of 150,000 kw approximately 15 per cent of the total output, or 22,500 kw, are generated by the gas turbine-generator.

Since thermal efficiency of a cycle with a fixed heat sink improves with an increased temperature entering the prime mover, a combined cycle efficiency improvement is expected since the gas turbine inlet temperature approximates 1500 F instead of the conventional steam cycle temperature of 1050 F.

Although a thermal improvement of 7.0 per cent is anticipated, there is certain developmental work needed before this cycle will be practical. First, larger gas turbine sizes must be developed to accompany the larger size steam turbine-generator units now being installed in the major systems in the United States. Units of 325,000 kw being installed in steam plants now, if replaced by the air-steam binary cycle, would require a gas turbine-generator of 50,000 kw rating. In the light of present gas-turbine development this would require two, 25,000-kw gas turbine-generator units, although it is understood units as large as 60 mw are being designed, and a 40-mw unit is being built at present. Second, it will be necessary to develop a coal burning gas turbine in order to provide universal application of the binary cycle. Much developmental work is still needed to perfect a satisfactory coal-fired gas turbine.

However, the 7.0 per cent cycle efficiency improvement, represents a major portion of the possible future gains for the steam cycle alone over the next 20 years. Starting with a 4500 psig, 1150 F-1050 F-1000 F, 450,000-kw unit in 1958, and assuming that steam conditions con-



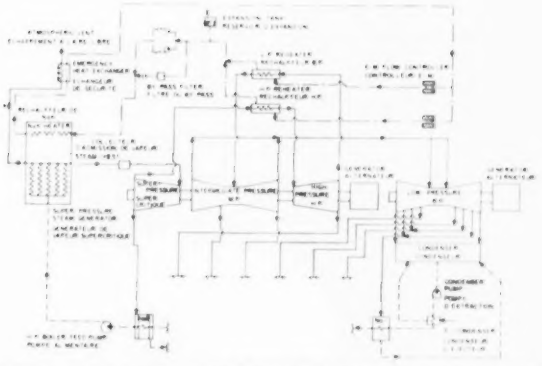


Fig. 8—Flow diagram illustrating liquid metal application to double reheat steam cycle

Fig. 9—Diagram of air-stream binary cycle

tinue to improve at the same rate as in the past, it can be predicted that in 1980, the steam cycle would incorporate a 10,000 psig throttle pressure, 1400 F throttle temperature, and two reheats at 1300 F and 1250 F. Assuming a 1000-mw turbine-generator at the future date, operating with an optimum feedwater cycle, a station heat rate of 7750 Btu per kwhr is anticipated. This represents only a ten per cent improvement over the 1958 cycle efficiency. Furthermore, the investment involved in future supercritical steam plants will be considerable.

It appears, therefore, that the thermal improvement provided by the binary air-steam cycle represents a significant advance over the steam cycle by itself and warrants careful study of cycle development and practical coal-fired gas-turbine development.

Conclusion

It does not appear possible to increase steam cycle efficiencies so as to realize in the future the great gains which have been made in the past 25 years. However, ingenuity of the engineer and thermodynamicist in the past few years has resulted in worth while reductions in heat rates, some of which have been detailed herein. Some possible methods for future improvements which appear to have merit were mentioned.

It would seem that any major reductions in cost of producing a kwhr of electricity must be obtained through development of a new and less expensive source of energy other than the fossil fuels. While nuclear energy offers this long-range promise, it does not appear achievable in most areas of the United States in the near future. In the meantime, every effort must be mobilized to achieve those gains, however small, that can be economically justified, to hold the line on power costs in the face of increasing fuel, labor, and capital costs. The power industry has in the past made an enviable record in this respect and is equalled by few and exceeded by none.

Summary

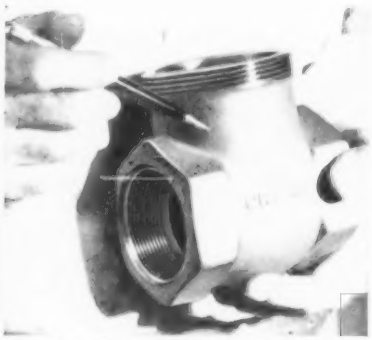
The purpose of this paper is two fold. First, discussion of economic studies, which have provided the basis for economies in construction, fuel and labor components in electric generation costs, is presented. Second, economic studies are reviewed which are related to future development, future in the sense that either the art of power generation has not progressed to the point of practical utilization of the systems studied, or the economic factors are not sufficient to justify present adoption.

Economic studies which have affected the installation of recent capacity include turbine-generator unit size, selection of turbine-generator type, higher initial pressure and temperature, reduced steam-generator exit gas temperature and improved design concepts in building, piping, coal handling and electric terminal facilities. The effect of these economies has been to offset the inflationary trend in fuel, construction and operation, but this cannot be maintained indefinitely. Consequently, we have reached a point in time when greater economy in construction methods, improved utilization of fuel and careful assignment of operating labor is of importance, if this present tremendous cost momentum is to be offset.

Future improvement studies encompass the areas of feedwater cycles, supercritical pressure and high temperature, use of liquid metal as a heat transport medium for the double reheat cycle, and the air-steam binary cycle. These studies indicate that future gains in steam cycle efficiency will not be as great as the gains made in the past twenty-five years. However, the ingenuity of the engineer and the thermodynamicist in the past few years has resulted in worth while reductions in heat rate, and it is hoped that such new generating concepts as the air-steam binary cycle will provide continued improvement.

Expanded-type body rings. Made from Crane Exelloy—a 12% chromium stainless steel. Provide a hard surface that resists abrasive damage, indentation and scoring by foreign matter. Rings are rolled in, can't work loose. Seating wear is taken by easy-to-replace bronze disc.

Quality in every detail inside and out. In rising and non-rising stem patterns—¼ to 3 inches—screwed ends. Working pressures: 200 lb. steam, 550° F.; 400 lb. non-shock cold water, oil, gas and air, 150° F.



Cylindrical body shape. Proved on high-pressure steel valves. Increases body strength without adding bulk. Distributes pressure uniformly. Reinforces seating area against distortion and chance for leaks.

12% chromium stainless steel seat rings make Crane 200-pound bronze gates last longer

Here is a close-up of Crane quality that shows you why these 200-pound bronze gate valves perform more dependably than ordinary bronze valves, with less maintenance.

For example, instead of integrally cast seats, they have long-wearing 12% chromium stainless steel body rings. Rings are rolled in . . . can't work loose in service. This also prevents leakage around rings. The quickly replaceable bronze disc takes normal seating wear.

Crane 200-pound bronze valves are competitively priced with bronze valves which do not have these and other important features. Why pay for less than Crane offers you? For complete facts, see your Crane Representative.

Write for Circular AD-2285. Gives complete technical data on both rising and non-rising stem patterns.

CRANE® VALVES & FITTINGS

PIPE • PLUMBING • HEATING • AIR CONDITIONING

Since 1855—Crane Co., General Offices: Chicago 5, Ill. Branches and Wholesalers Serving All Areas

By IGOR J. KARASSIK*

Worthington Corp.

The boiler feed pump and its associated equipment represent a major operating and maintenance consideration in today's power plant. Here we run in question and answer form a series of clinic sessions on various boiler feed pump prob'ems. The replies are the work of one of the topmost pump authorities and give specific information which we hope will prove valuable to our readers.

Steam Power Plant Clinic—Part VII

QUESTION:

We are working out the miscellaneous piping arrangement for the boiler feed pumps we have purchased to serve our new 100,000 kw, 1800 psi unit. The pumps are designed to handle 500,000 lb hr of 320 F feedwater, taking their suction from a deaerating heater. The suction pressure is approximately 100 psig and the discharge pressure 2100 psig. The pumps are provided with a balancing device and we are undecided on the choice between returning the balancing device leak-off directly to the pump suction and running the return lines all the way to the deaerating heater. Can you outline the advantages and disadvantages of both arrangements?

ANSWER:

Whenever multistage pumps are equipped with a balancing device to counteract the axial thrust generated by a group of single suction impellers all facing in the same direction, it is necessary to return the balancing device leak-off into the cycle at some point where the pressure is approximately equivalent to the suction pressure. Thus, as you state, the choice of this point of return is limited to the pump suction itself and to the deaerating heater. Of course, the main advantage of returning the leak-off directly to the pump suction is that the line will be very short. As a matter of fact, it can be made an integral part of the pump piping, Fig. 1, and no isolating valve will be required for it.

On the other hand, it is necessary to consider that the feedwater is subject to a definite temperature rise at light load operation. Generally, this temperature rise is limited to something like 15 deg F by means of a recirculation bypass which is made to open automatically whenever the feedwater flow through the pump falls to a value which causes the temperature rise through the pump to reach this figure. In addition, the balancing device leak-off itself undergoes a further temperature rise as it flows through the balancing device because of the degradation of pressure energy.

We can make some approximate calculations to give us an idea of the order of magnitude of this additional temperature rise. If the pump develops 2000 psi net

* Consulting Engineer and Manager of Planning, Harrison Div.

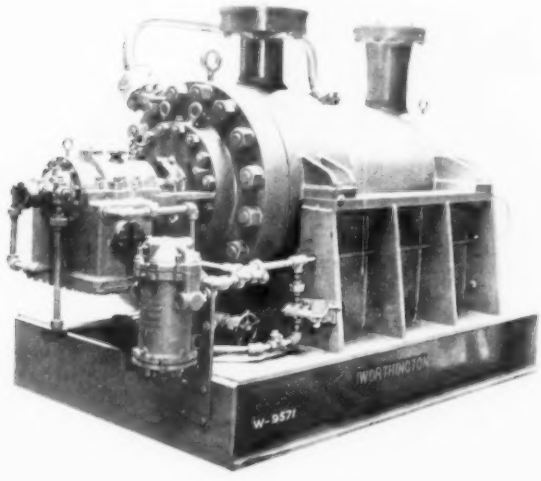


Fig. 2.—To reduce piping costs leak-off and recirculating lines are sometimes manifolded as here. The manifolding must, however, take place after the pressure reducing device and any valves in the recirculation

Fig. 1.—The main advantage of returning a leak-off directly to the pump suction is the line is very short and can be made integral with the piping

pressure at rated flow (2100 psig discharge pressure less 100 psig suction pressure) and if it handles 320 F feedwater (specific gravity = 0.908), the design total head will be 5060 ft. Assuming that the pump has a rise toward shut-off of about 18 per cent, the total head at minimum flow will be close to 6000 ft. This will be the energy that is destroyed in the balancing device and the rise in leak-off temperature can be determined by reference to Tables of the Properties of Compressed Liquids. As a quick approximation (and one which will err on the safe side) we can obtain this rise by dividing the 6000 ft by 778, the ft-lb equivalent of a Btu, and assume that the additional rise in temperature over and above the temperature rise through the pump itself will be 7.7 deg F. The temperature of the balancing device leak-off can therefore exceed the temperature of the feedwater at the pump suction by 22.7 deg F, if the maximum temperature rise through the pump is held to 15 deg F.

Thus, if the balancing device leak-off is returned directly to the pump suction, it will mix with the incoming feedwater and raise the temperature of the mixture. If the pump has been selected fairly close to the margin from the point of view of NPSH conditions, this rise of suction temperature may prove to be dangerous. In addition, transient conditions of sudden load changes may reduce the available margin in NPSH and the installation which may be safe under stable conditions will become marginal at times of swinging loads. On the other hand, returning the leak-off to the deaerating heater, where the heat picked up in the pump proper and in the balancing device can be dissipated, will not only eliminate this temperature rise of the feedwater at the suction, but will also act beneficially on the feedwater in the heater during load swings.

My recommendation, therefore, is to return the balancing device leak-off to the deaerating heater, even though it means some additional expense in piping and valving.

The manufacturer of the deaerating heater should be given full information as to the amounts and temperatures of this leak-off, so that he may provide for it in the heater. He will have to decide whether to introduce it below the water-line in the storage space or whether to bring it in above the water level and provide some sort of perforated pipe through which to spray the returns into the steam space. This last arrangement is frequently used when returns to the heater are at a much higher temperature than that corresponding to the heater pressure. It is important to give the heater manufacturer both the quantity of leak-off under "new pump" conditions and the estimated flow when the pump is worn.

The return line should be so arranged that the back pressure on the balancing device may not be inadvertently increased over the value of the suction pressure. Therefore, while this return piping needs to be valved-off to permit the dismantling of the pump when necessary, any valve interposed between the balancing device relief chamber and the final return point should be securely locked in the open position. The operators should be warned to make sure that if this valve is ever closed during inspection or overhaul, it must be opened again before the pump is allowed to be started up.

In order to reduce piping costs, the leak-off and recirculating lines are sometimes manifolded, as shown on Fig. 2. Of course, the manifolding must take place *after* the pressure reducing device and *after* any of the valves located in the recirculation line.

QUESTION:

Our boiler feed pumps are provided with condensate injection seals in place of the conventional stuffing boxes. What is considered as the maximum allowable temperature of the supply water to these seals? We would also like to know whether a means has been devised for getting rid of the seal cover drains other than the trap arrangement that we use. The traps are, of course, drained back into the condenser.

ANSWER:

It is preferable to use injection water at temperatures under 120 F so as to avoid the slight steaming at the seal covers which would take place if injection temperatures in excess of that figure were used. This steaming is undesirable partly because of the concern it may arouse in the operators and partly because of the possibility of its condensation near the pump bearings.

In addition, pumps arranged for condensate injection sealing generally are not provided with any other cooling means in that area. If the shaft sleeves rotating within the condensate seal breakdown bushings are not adequately cooled, the heat from inside the pump will travel through the shaft to the pump bearings. It is true that the lube oil is extremely cooled while passing through an oil cooler. Nevertheless, this additional heat at the bearings may be injurious to their life.

Actually, there is little reason to expect that the injection temperature would exceed this figure of 120 F, if the injection supply is taken, as it should, directly from the discharge of the condensate pumps.

Two different systems are used to dispose of the drains coming from the collecting chambers of a pump fitted with condensate injection seals. The first, used in your case, utilizes traps which drain directly to the condenser. The second, collects the drains in a condensate storage tank into which various other drains are also returned. This tank is under atmospheric pressure and, therefore, must be set at a reasonable elevation below the pump centerline, so that the static elevation difference will overcome friction losses in the drain piping. A pump then transfers the condensate drains from the storage tank into the condenser.

To my knowledge, no specific difficulties have taken place in installations where the injection sealing condensate is evacuated through traps, except for an isolated case of trap malfunctioning. While I have no details on the cause of this malfunctioning, I believe that proper maintenance of this equipment should hold such occurrences to an absolute minimum. I should add that a minor problem may arise when boiler feed pumps are operated during the initial start-up, before condenser vacuum is established. This causes a rise in the back pressure on the seal drains and, unless provision is made

to relieve this back pressure, some overflow of injection condensate may take place at the seal covers.

There are no major advantages to one system of evacuation over the other and the choice between the two is dictated primarily by personal preference. However, when the boiler feed pumps are located at the lowest plant elevation (as, for instance, in some outdoor plants) it becomes necessary to use traps, since insufficient elevation difference would exist to drain from the collecting chambers to an open tank. I know of one exception, where a small sump is provided between the three pumps serving the main unit and a vertical sump pump is used to transfer the drains into the condenser.

It should be noted that the drains from the collecting chambers are saturated with air because of the turbulence which exists in the chambers. As a result, it has been found necessary in a few installations to provide breather pipes in the drain lines, to avoid the accumulation of air pockets caused by the separation of the entrained air. Until these breather pipes were installed, the evacuation of the drains was erratic and some "cyclic" spill-over took place at the seal covers each time that a slug of air formed in the drain piping. A small geyser would rise from the collecting chamber vents. Building up of the static head in the collecting chamber would then force the slug of air out through the piping and the "geyser" would subside. The installation of a breather, or "burp" pipe at a suitable location eliminated the problem entirely.

It is extremely important that the drain piping be selected with ample proportions to handle the increased amount of drains which will flow from the collecting chambers once the pump has become worn and internal clearances between the sleeves and the breakdown bushings have increased. As a rule of thumb, provision should be made for a flow of two to two and a half times the initial flow. Otherwise, the increased friction losses through the drain piping will raise the back pressure on the chambers and proper evacuation will be unattainable.

QUESTION:

Our high-pressure boiler feed pumps operate in a closed cycle, that is the condensate pumps discharge directly into the suction of the boiler feed pumps through several closed heaters. The pump nameplate rating indicates a full load temperature of 330 F, which was probably the temperature expected at the feed pumps when these were ordered. In service, we have found out that the temperature at the maximum turbine capability conditions exceeds this nameplate rating and reaches 347 F. What are the principal factors which would determine the maximum suction temperatures allowable on our boiler feed pumps? At maximum turbine capability, the suction pressure is 245 psig. The pump proposal curve shows that the minimum required NPSH at 1350 gpm (this is the rated capacity) is 47 ft.

ANSWER:

Two separate limitations on temperatures have to be considered in the case of boiler feed pumps operating in a closed cycle. The first is a strictly mechanical limitation and in this particular case need not concern you. High-pressure boiler feed pumps have been built for operating temperatures in excess of 450 F and I am certain that the 17 deg F higher temperature than that indicated on the nameplate will cause no mechanical difficulties.

The second limitation is of a hydraulic nature and here again you will find that in your particular case ample margin is available. This limitation is tied with the availability of sufficient NPSH at the pump suction. The net positive suction head is defined as the energy in feet available over and above the vapor pressure corresponding to the pumping temperature, and it must always be equal or greater than the required NPSH. This latter is a function of the geometry of the first stage impeller, of the capacity handled by the pump and of the operating speed.

The required NPSH of 47 ft at a pump flow of 1350 gpm can be used in establishing maximum permissible temperatures. Conversely, it can also be used to determine the minimum permissible suction pressure for any given operating temperature. The relations to be used for this sort of computation are the following:

$$\begin{pmatrix}\text{Maximum vapor pressure for a given flow and with a given minimum suction pressure.}\end{pmatrix} = \begin{pmatrix}\text{Minimum suction pressure at that flow.}\end{pmatrix} - \begin{pmatrix}\text{Required NPSH at that flow.}\end{pmatrix}$$

and conversely,

$$\begin{pmatrix}\text{Minimum suction pressure for a given flow and a given temperature}\end{pmatrix} = \begin{pmatrix}\text{Vapor pressure for that temperature.}\end{pmatrix} + \begin{pmatrix}\text{Required NPSH at that flow.}\end{pmatrix}$$

In the first relation, once the maximum vapor pressure has been established, the maximum temperature can be obtained from the Steam Tables.

For instance, what is the maximum temperature if the pump handles 1350 gpm and the suction pressure is 245 psig? Converted to pressure units at pumping temperature, the NPSH is approximately 17 psi. Using the first relation, we establish that the maximum permissible vapor pressure will be 245 less 17, or 228 psig (equivalent to 242.7 psia). This is the vapor pressure of water at approximately 398 F and this is our maximum permissible operating temperature under the conditions we have selected. While it is well above the 347 F you mention, and while you will never encounter 398 F

operating conditions, you must consider the possibility of reduced suction pressures caused by a host of possibilities. For instance, transitory reductions in current frequency will reduce the discharge pressure of the condensate pumps and, therefore, feed pump suction.

We should therefore use the second relation to determine what is the minimum suction pressure for handling 1350 gpm at 347 F. The vapor pressure of 347 F is 129.5 psia or 114.8 psig. At this temperature, the specific gravity is 0.894 and 47 ft corresponds to 18.2 psi. Therefore, the minimum permissible suction pressure is 133 psig.

Exerpts From AEC Twenty-Fifth Semi-Annual Report

Boiling Water Reactors

In a direct cycle boiling water reactor, water boils in the reactor core, forming saturated steam which flows directly to a turbine. This system makes possible a relatively simple design with advantages in performance and low costs. For most boiling water reactors no intermediate heat exchanger is used to transfer heat from the coolant to another medium, and in such a direct cycle system, the temperature at the turbine throttle is essentially the same as the reactor outlet temperature.

BORAX-4, the most recent of this series, operated from December 1956 until it was shut down in June 1958. This reactor designed for 20 tMw, was used principally to test high thermal capacity fuel elements made from mixed oxides (ceramics) of uranium and thorium. These elements have the advantage over metallic elements that they do not become distorted under intense radiation, and, in the event of a failure of protective cladding, are much less reactive with water. BORAX-4 was operated satisfactorily with several experimental defective fuel elements in the core. All the Borax facilities were operated at the National Reactor Testing Station under direction of Argonne National Laboratory.

A new 30,000 tMw version of the BORAX facility, BORAX-5, is planned to investigate the practicability of using nuclear power to superheat reactor-produced steam. It would make in-reactor tests of the best fuel element design for a full-scale boiling and superheating core. Such a core might then be built and BORAX-5 operated as a demonstration reactor to investigate the potential advantages of nuclear superheat in lowering power generation costs.

Based on the results of the earlier BORAX experiments, Argonne National Laboratory placed in operation in late 1956 at Lemont, Ill., the Experimental Boiling Water Reactor (EBWR). The EBWR was designed for 20 tMw. It has been operated stably at 61.7 tMw without change in the number of fuel elements. The large increase in power was possible because natural circulation of water in the core proved much greater than believed possible, and because contrary to expectation the reactor operated stably despite the increased amount of steam in the reactor core caused by high power operation. As of November 30, the EBWR had produced more than 27 million kilowatt hours of electrical power from its turbine generator rated at 5000 ekw.

The architect-engineering firm of Sargent & Lundy, Chicago, has been awarded a contract to design the equipment required for converting EBWR to a 100 tMw plant. Argonne scientists and engineers are designing a modified core. Other changes will include installation of new heat exchangers, and construction of heat removal equipment and a new cooling tower. No additional electrical generating capacity will be provided, but the additional heat will provide steam for the laboratory's central heating system. Completion is scheduled for late 1959.

Fast Breeder Reactors

Fast reactors occupy an important place in nuclear power programs because their ability to produce more fuel than they consume is potentially important to conservation of fissionable material resorces.

The first experimental fast reactor was the Experimental Breeder Reactor No. 1 which has been operated at the National Reactor Testing Station since 1951. With its first core, the EBR-1 demonstrated that breeding is feasible in a fast reactor. Operation with its second core in 1955 was terminated during an experiment by a power excursion which resulted in partial meltdown of the core.

Successful operation during 1958 with a redesigned third core indicated that the excursion was caused in part by an insufficiently rigid core structure. After extensive experiments with both rigid and nonrigid cores, the Commission plans to test plutonium fuel elements in EBR-1.

Construction of an additional facility for testing the safety of fast reactor systems, the Transient Reactor Test Facility (TREAT), was completed in October at the National Reactor Testing Station. The primary objective of TREAT is to provide data on the mechanism of melting of fuel elements by nuclear heating. Initial experiments will be directed toward fast reactor fuel pins.

The second major experimental power reactor in the Commission's fast reactor program is the Experimental Breeder Reactor No. 2, a 16,500 net ekw plant now under construction at the National Reactor Testing Station. At the end of 1958, construction was 15 per cent complete. The reactor is scheduled for dry criticality in May 1960. Both EBR plants were designed by Argonne National Laboratory, which also operated EBR-1.

A fuel reprocessing and fabrication facility is included as an integral part of the installation. EBR-2 will be the first reactor in the United States to operate on a closed, pyrometallurgical fuel cycle. Thus, for the first time, it will be possible to evaluate the technical and economic advantages associated with pyrometallurgical processing of core elements and their fabrication by remote handling equipment on the basis of actual operating experience. EBR-2 will also demonstrate operation of large-scale sodium components, such as pumps and heat exchangers, under pressure and temperature conditions comparable to those required for high performance, full-scale reactors.

By Dr. ING. G. NOETZLIN, VDI
and DIPL. ING. A. ENGL, Marl

First European Supercritical Power Plant: Design and Experience—Part I*

IN THE field of steam power engineering the most advanced power plants have increased steam temperatures to 1110 F and 1200 F and use austenitic steel while raising pressures into the supercritical steam conditions of 4280 psi and 5000 psi.

The vital data for the first three plants employing supercritical pressure are shown in Table I. Several additional units with primary steam pressures to 3400 psi and above and with temperatures to 1110 F and higher are being built or planned in the United States. In Germany, one plant with 3270 psi and 1110 F is about to be started up, another for 4280 psi and 985 F has been ordered. The American Eddystone plant is designed for a steam flow of 2 million lb per hr which is extremely high compared to German conditions. It has the advantage of specifically increasing turbine efficiencies. The size of 85 Mw selected for the Huels unit with 550,000 lb per hr steam flow was the maximum justifiable for an overall system capacity of 285 Mw.

Approximately 85 variations of the steam power cycle

* Summary of two papers presented at the annual meeting of the "Vereinigung der Grosskesselbesitzer" (Association of Power Boiler Operators, VGB) in Bremen, 1958.

The full text was published in the magazine of the Association, No. 55 (1958), pp. 230-264. The summary was published in "Brennstoff-Warme-Kraft" (BWK), Vol. 10, No. 10 (October, 1958), pp. 481-487 and was translated from the German by Dipl. Ing. W. W. Schroedter, Combustion Engineering, Inc.

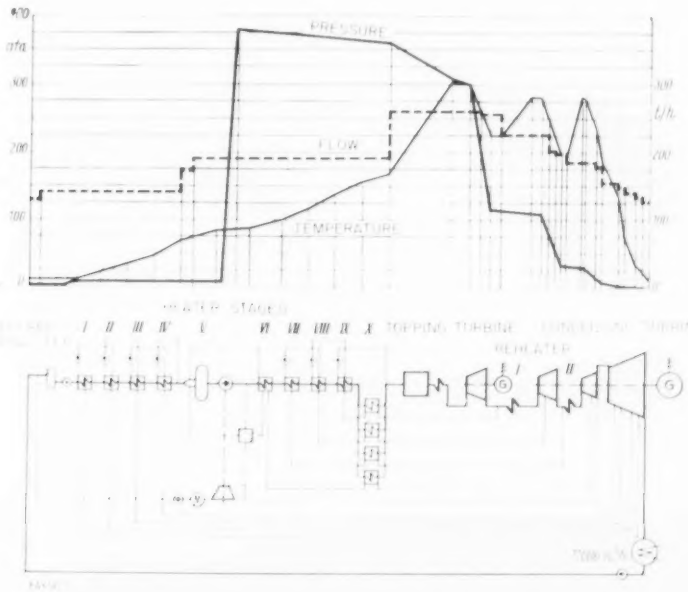


Fig. 1—Heat flow diagram

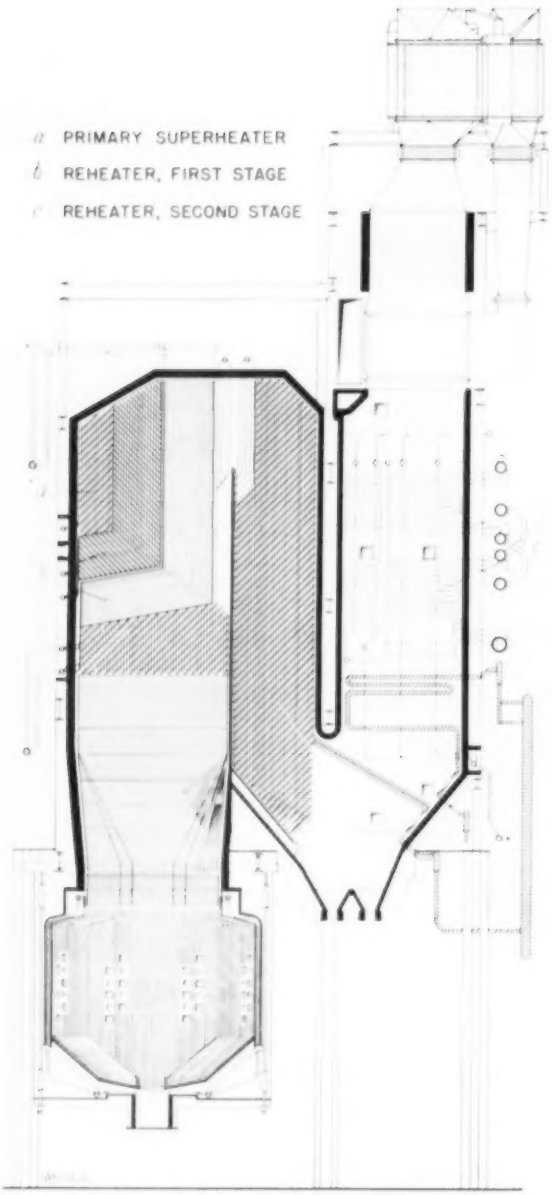


Fig. 2—Benson steam generator for 550,000 lb per hr, 4260 psig, 1101 F, with double reheat

were thoroughly calculated to serve as a basis for the proper selection. Some of the results are tabulated in Table II for a 4250-psi plant. They show in addition to the increase in primary steam conditions, attention must be paid to other measures which applied at proper places, may lower the heat rate at less expense. The fact that these measures often entail a complication of the plant, must be accepted for a highly advanced, base loaded power plant.

The production cost of power, however, depends not only on the heat rate, but to the same degree on the use factor and the investment requirements of the plant. Because the Huels unit exclusively serves a chemical plant operating around the clock, a high use factor was assured. The influence of fuel costs and of heat rate therefore predominates and justifies additional costs for high pressure and temperature more easily than it would, for instance, for a public utility.

The flow diagram and the finally selected arrangement is shown in Fig. 1. Of 575,000 lb per hr of primary steam, less than 49 per cent are removed in the main condenser and 5 per cent in the condenser of the feed pump turbine. 46 per cent of the steam flow is used for regenerative heating in the four low pressure feedwater heaters, a deaerator, and the four high pressure feedwater heaters. The condenser is designed for 0.355 psia corresponding to 51 F cooling water. Detailed calculations showed that despite a 58 F yearly mean temperature of the river water the additional capacity available during the winter months justified the larger size of the low pressure section of the condensing turbine.

The high pressure feedwater heaters are divided into four parallel circuits. Each of the 1700 psi heaters of stage IX is followed in the water circuit by a cooler-heater. The four coolers are connected on the steam side to the extraction stages VI, VII, VIII or IX. The condensate of both the low pressure and high pressure stages is returned to the circuit by pumps.

Steam Circuit

The primary steam piping consists of six parallel lines which connect directly to the six outlet headers of the steam generator. The pipes have 4.77-in. O.D. and a wall thickness of 0.866-in. from austenitic piping material 18 12 MVS, corresponding to DIN (German Industry Standard) grade XSCrNiMoVNb 16 13 (Table III). Three pipes each terminate in the two steam strainers which are contained in the distributing header ahead of the turbine. There are no boiler stop valves. The first valves are the four main stop valves of the topping turbine; the primary steam piping is therefore considered a part of the steam generator.

The 4580-psi piping system is protected by two safety valves in parallel to the topping turbine with the steam passing into the 1700-psi system. The safety valves of the 1700-psi system blow off into the 425-psi system which only then following the second stage reheater has safety valves connecting to atmosphere. The arrangement assures that both reheaters are still cooled by the full steam flow in case the high pressure safety valves go into action.

The hot reheat lines of the 1700-psi system are also made of austenitic steel 18 12 MVS with 9.5-in. O.D. and 0.63-in. wall thickness.

The steam generator is started up with the water extending right up to the main valves of the 4250-psi machine. The water flows from the distributing header through startup piping to the startup separator. The reheaters are cooled by 28.4-psi process steam which enters through cooling steam piping ahead of the first stage reheater and flows through both stages. The primary startup flow is usually 330,000 lb per hr at 2130 psi, while up to 77,000 lb per hr is used for cooling of reheaters. An extraction line connects the startup separator to the steam generator at a mixing header ahead of the austenitic superheater surface. This avoids having water enter the hot austenitic tubing during shutdown.

The Benson steam generator, as shown in Fig. 2, is built as a three-pass unit with open slagging furnace.

The unit contains a 25,000 sq ft total of heating surface of austenitic material, representing 32 per cent of the total heating surface. The heated austenitic tubes have $1\frac{1}{16}$-in. O.D. with 0.138-in. to 0.266-in. wall thickness. The high pressure made it necessary to change from ferritic to austenitic tubing already at 895 F steam temperature or 970 F metal temperature instead of at 985 F steam temperature as customary in the pressure range of 2270 psi to 2550 psi.

The extension graduation of tubing wall thicknesses utilizes the end section of each austenitic heating surface to the limit of its allowable strength. The maintenance of the calculated temperatures during operation is therefore very important. In addition to the standard temperature measurements at the mixing headers and at other characteristic points, 280 other temperature measuring points have been provided, some of them on individual elements, some on cross-over piping.

The steam generator has two injection points: the main injection, I, still in the ferritic zone but immediately ahead of the austenitic surface, and the correcting injection, II, ahead of the final stage superheater. The injection stage I receives its main impulse from the steam temperature following the desuperheater and its corrective impulse from the injection flow of the second stage. The desuperheater of the second stage is at the same time the final steam mixing point. It is an austenitic forging and as such sensitive to abrupt temperature changes. The corrective impulse of injection stage I from the injection flow of stage II levels the temperature variations sufficiently to keep the rate of change to within 5.5 deg. F per minute. The final six steam temperatures show only differences of 7 deg. F to 9 deg. F which is almost within the measuring accuracy provided.

While the primary steam temperature is ultimately controlled by the fuel-steam ratio together with a quick acting correction by injection, the final temperature of the first stage reheat is to be held constant by heat exchange with the second stage reheat. The characteristics of the first reheater with purely radiant heat absorption and that of the second reheater with purely convection surfaces effect a transfer of heat as a function of load. After passing the first platen section, the high pressure reheat steam is passed through twelve rotary valves either to the heat exchanger or bypassed directly to the second platen section under control of the final temperature. The outlet temperature of the second reheater is to be controlled by dampers in the gas pass. This in turn also influences the absorption of a heating surface in the primary circuit and thereby finally returns fuel input into equilibrium with total heat output.

The steam generator is equipped with four direct firing pulverizers and has an open slagging furnace with a 50 per cent waistline contraction. The high feedwater temperature together with 266-F exit gas temperature required the placement of superheater surfaces as part of the tubing in the slagging furnace, which has a 16-cornered cross-section in order to equalize the absorption rates. Fuel is injected at eight corners with four burners each and with two mills supplying each corner. This achieves a satisfactory fuel distribution also when operating only with three mills.

Turbines

The topping turbine for 4260 psig and 1110 F, Fig. 3, at 16 Mw output is designed as a reaction turbine in a barrel type outside casing. The inside casing and the rotor are fabricated from a 12 per cent Cr steel. The only parts of austenitic material are the sleeve on the rotor carrying the first ten stages and the first six rings of the high pressure seal, the first stationary blade support, the high pressure seal with its attachment rings and the four steam inlets. The austenitic parts are connected with the rotor and the casing by radial bolts to permit thermal expansion. The four steam inlet sleeves and the two exhaust openings are the only parts which interfere with complete radial symmetry.

TABLE I—DESIGN DATA FOR THE FIRST THREE POWER PLANTS WITH SUPERCRITICAL PRESSURE

Operators	Chemical Works Huels	Ohio Power Co.	Philadelphia Electric Co.
Plant	Plant No. 2 Unit No. 1	Philo, No. 6	Eddystone, No. 1
Date of startup	Nov. 1956	March 1957	1959
Turbine arrangement	Two shafts	Single Shaft	Two Shafts
Rated output, Mw	85	125	325
Steam flow, lb per hr	572,000	675,000	2,000,000
Primary Steam, psig/F	4250/1112	4800/1150	5000/1200
1. Reheat, psig/F	1535/1040	1150/1050	1065/1050
2. Reheat, psig/F	454/1040	177/1000	270/1050
Pressure in Condenser inch Hg	0.724	1.00	1.50
Heater Stages	9	7	9
Feedwater temperature degree F	638	527	572
Heat rate, Btu/kwhr	8251	8500	8019

An interesting solution was found for the design of the steam distributor, Fig. 4, arranged below the topping turbine with twelve inlet and outlet openings. Connected in series are individual spherically formed elements each of which has one or two pipe nipples reinforced by cuffs. The connections are fitted with half cylinder plates welded together and designed to take load when the inside walls are pressed against them under operating pressure conditions. Three primary steam pipes connect to each of two strainer heads using pressure seals. These and similar spherically formed elements made it possible to avoid the much larger wall thicknesses of customary header designs.

The 71-Mw condensing turbine for the high pressure reheat steam conditions of 1560 psig and 1040 F has been built as a reaction turbine in four casings with a triple flow exhaust section. Austenitic steel is used for the steam piping, for the valve groups located on either side, and for the inlet sleeves of the first casing only. The latter are also steam cooled. The first two casings utilize a double shell, each with horizontal cylinder flanges. In

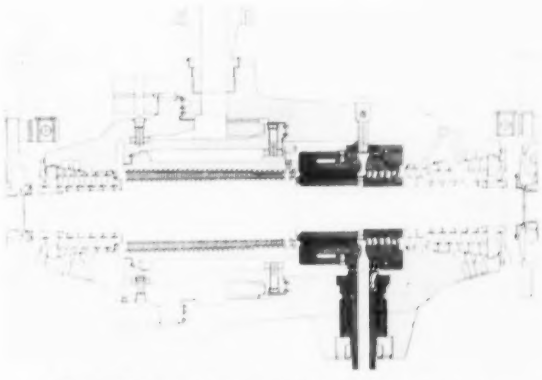


Fig. 3—Topping turbine for 16 Mw, 4260 psig, 1110 F.

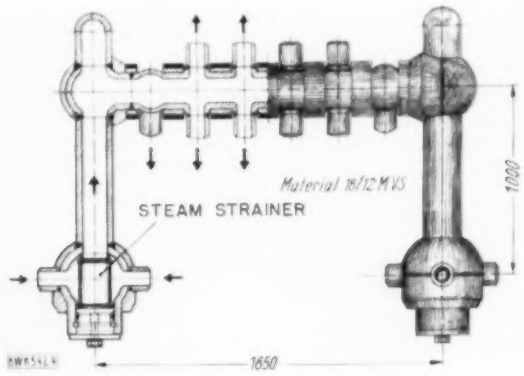


Fig. 4—Primary steam distributing header fabricated with spherically formed elements

side and outside shells can expand independently of each other. The inside shell of the second casing is made of a steel casting with 12 per cent Cr. The absence of an impulse stage here produces the highest temperature stresses in the turbine. The outside shells of the first two casings utilize a normal low alloy, Mo-steel casting. This material also suffices for the inside shell of the high pressure section because temperatures are reduced by use of an impulse stage.

Feed Pumps

The feed pumps shown in Fig. 5 have variable speed drive. A feedwater valve is not required. In conjunction with sliding pressure operation this considerably reduces auxiliary power requirements at lower loads. Because of the sliding pressure operation, the high pump speed and the comparatively low suction head, the water is delivered to the feed pumps by slow speed suction pumps coupled to the main pumps by Stoeckicht gears.

The two feed pumps have been designed for 110 per cent of boiler load and at 5075 rpm have a capacity of 605,000 lb per hr with a head of 5820 psi. They have normal hydraulic thrust balancing protected by a mechanical disengagement during startup until the speed reaches 4000 rpm. The usual pump design with individual stages bolted together on the outside was abandoned because of the high discharge pressure in favor of assembling the stages inside a barrel-type casing in which the elements are compressed by the discharge pressure. Only the one seal area between casing and cover plate must now hold against atmospheric pressure. The reserve pump is able to start and take over load within 20 seconds.

The feedwater piping was designed as strip-wound pipe. An inside pipe from 13 Cr Mo 44 material having only 55 per cent of the wall thickness required for a standard drawn pipe, is wound with several layers of strips with 0.128-in. thickness. The inside pipe is required to take only the full axial stress with the wound material carrying the balance of the tangential stress. The strip-wound type pipe has the advantage over a standard pipe in greater flexibility and therefore may be laid out with comparatively small radii. This fact is of particular advantage for the connections between the closely arranged feedwater heaters.

TABLE II—POSSIBILITIES OF IMPROVEMENT FOR A 4250-PSIG PLANT

Increase of	By	Improvement Btu/kwhr
Primary steam pressure	142 psi	7.5
Primary steam temperature	18 F	15.1
Steam temperature leaving first reheater	18 F	15.1
Steam temperature leaving second reheater	18 F	11.9
Vacuum at constant turbine exhaust loss	0.289 in. Hg	99
Turbine efficiency in topping turbine	1%	11.1
Turbine efficiency in each casing	1%	72.6
Turbine exhaust area	20%	25.0
Feedwater temperature entering economizer		
By additional regenerative heater	from 536 F to 617 F	32.1
By additional separated cooler	from 617 F to 638.5 F	23.8
By additional pump for HP heater condensate		63.1
Efficiency of feedwater pump	1%	3.2
Decrease of		
Overall auxiliary power	100 kw	9.5
Pressure drop in		
Economizer, waterwalls and superheater	142 psi	6.7
1st reheater	28.4 psi	17.8
2nd reheater	14.2 psi	32.6

Plant Costs

The unit costs of the plant amounted to $109.8 kw compared to the costs of a standard plant of same size calculated at $99.5 kw in 1955. The lower heat rate is therefore required to cover an additional expenditure of about $900,000. This would be achieved under full load use of the plant in 3400 hr per year, assuming a comparatively favorable fuel price of 60¢ per million Btu. The plant has in the meantime operated for 8000 hr and achieved an average heat rate of 9170 Btu kwhr during the first quarter of 1958.

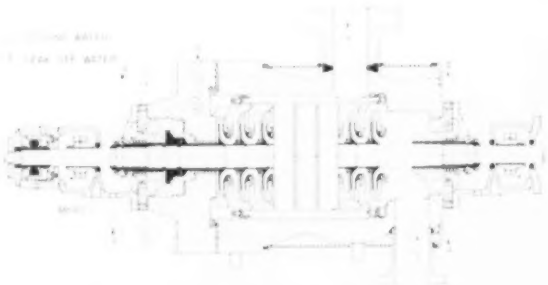


Fig. 5—Boiler feed pumps for 605,000 lb per hr, 5830 psig, 5075 rpm.

Operating Experience

Using supercritical pressure has not been a handicap to operation. Special problems are caused by the high pressure only where large differentials occur in an expansion process, as for instance at the seals of pumps, at the throttling locations of injection valves or pressure reducing valves or also at points of leakage. These difficulties can be overcome by proper design and material selection.

The high temperatures, however, with their requirements for austenitic materials do impose various restrictions on operation. Limiting in particular the rate of temperature changes during startup and shutdown of individual sections as well as during malfunctions requires well-trained operating personnel and well-functioning controls and instruments. Design features which were successful for ferritic steel, may not always apply for austenitic materials.

In addition to the usual initial difficulties there were two occurrences during operation to date, which caused extremely disrupting failure.

Infiltration of sodium hydroxide into the feedwater caused by several simultaneous operational mistakes in the feedwater treating plant during regeneration of an anion filter led to extensive damage in the austenitic section of the steam generator by stress corrosion. Approximately 140 ppm of hydroxide were added to the feedwater while the steam generator was being shutdown. Only 25 minutes after the contaminated feedwater has entered the steam generator as shown by the conductivity recorders in the plant, damage to the tubing made it impossible to maintain pressure. Several tubes on the two sidewalls of second gas pass were torn off and about 100 other tubes had bad leaks.

The damages had all the characteristics of stress corrosion; the cracks usually showing transgranular passes with fine feathery type endings (Figs. 6, 7, 8, 9, 10).[1] The failures occurred only where tubes were subject to superimposed stresses. Straight tubes without attachments were not attacked. Most of the cracks in the $1^1/_8$-in. O.D. tubing with 0.138-in. wall thickness occurred next to radial weld seams. The tube sections with welded attachments also showed extensive attack. The first damage occurred ahead of the first desuperheater in a temperature zone ahead of and up to 788 F. The connecting tubes and side walls of the first gas pass immediately following the desuperheater were not attacked except where they again achieve fluid temperatures of 770 F. Following the more extensively damaged surfaces in the range of 770 F to 805 F, the attack frequency gradually ran out.

The apparent temperature relation of these damages was investigated by tests on a 1760-lb per hr experimental unit designed for 4250 psig and 1110 F. The solubility of sodium hydroxide in steam was found to be a function of both pressure and temperature. If the addition of the hydroxide exceeds the solubility, the hydroxide precipitates in molten form within a definite temperature range and as such acts as the electrolyte required for establishing stress corrosion. The minimum solubility is about 90 deg F to 108 deg F above the saturation temperature. Investigations of Styrikovich[2] have shown the solubility to increase again with higher temperatures. In the present case, sodium hydroxide did not precipitate in heating surfaces with temperatures above 842 F and therefore failed to cause damages.

A second case of damage to an austenitic part of the equipment occurred in the austenitic reducing station ahead of the 1700-psig back pressure piping. Here the energy released by expansion of the steam from 4250 psig to back pressure is destroyed and used for atomization of the injection water required for desuperheating. At lower loads poor atomization subjected individual austenitic parts alternatively with steam and injection water. Widespread cracking developed there after only several hundred hours of operation due to thermal shock (Fig. 11).[1]

[1] Figs. 6, 7, 8, 9, 10, 11 are discussed in greater detail in Part II and will be published with this part.

[2] M. A. Styrikovich, "Working Process in Once-Through Steam Generators at Supercritical Pressures," Report 254 G, 20 at World Power Conference Vienna 1956. Also Combustion, Vol. 28 No. 3 (September 1956), pp. 49-53.

TABLE III. COMPILATION OF AUSTENITIC STEELS USED AT POWER PLANT HUELS

Specification	C	Cr	Ni	Mo	V	N	B	Nb
X8CrNi Nb 16 13	0.1	16	13					$10 \times \%C + 0.4\%$
X8CrNi MoNb 16 16	0.1	16	16	1.6 to 2.0				$10 \times \%C + 0.4\%$
X8CrNi MoVNb 16 13	0.1	16	13	1.1 to 1.5	0.6 to 0.8	0.1		$10 \times \%C + 0.4\%$
X8CrNi MoBNb 16 13	0.06	16	13*	1.8			0.05	$10 \times \%C$

* Recently increased to 16% Ni in specification X8CrNiMoBNb 16 16.

Note: Nb (Niobium) is the symbol used in Europe for the element known in the anglo-saxon countries as Columbium, Cb.

The Paley Report in Retrospect For Steel

How accurately were the authors of the President's Materials Policy Commission report on "Resources for Freedom," based on 1950 statistics, able to foresee the present economic and technological position of the steel industry? This question was the basis for a paper presented at the annual meeting of the American Institute of Mining, Metallurgical, and Petroleum Engineers, Feb. 17, in San Francisco by John D. Sullivan, technical director of Battelle Memorial Institute.

While the PMPC report did not attempt to provide a curve showing annual growth for any given industry or commodity, Sullivan demonstrated that some comparison can be drawn between 1950 statistics for the steel industry and those for 1957. The report, issued in June 1952, and often referred to as the Paley Report, projected its predictions to 1975, with no attempt to fix the rate of growth and change from year to year in the intervening period.

Sullivan's analysis of the Paley report in retrospect indicated that "on the whole, the speculations on statistical matters appear to be realistic" for the portion of the report dealing with iron and steel. That is, the advances predicted in the original report on iron and steel capacity, production, and consumption are generally "on schedule." The Battelle technologist, however, points out that at this stage it would appear that technological advances, while being made, are not all in the direction predicted.

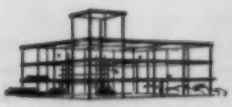
SURFACE CONDENSERS

FEEDWATER HEATERS

EVAPORATORS

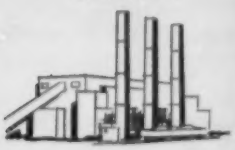
GANTRY CRANES

HOISTS

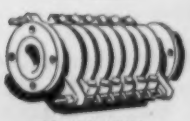


STRUCTURAL FABRICATION AND ERECTION

STORAGE TANKS



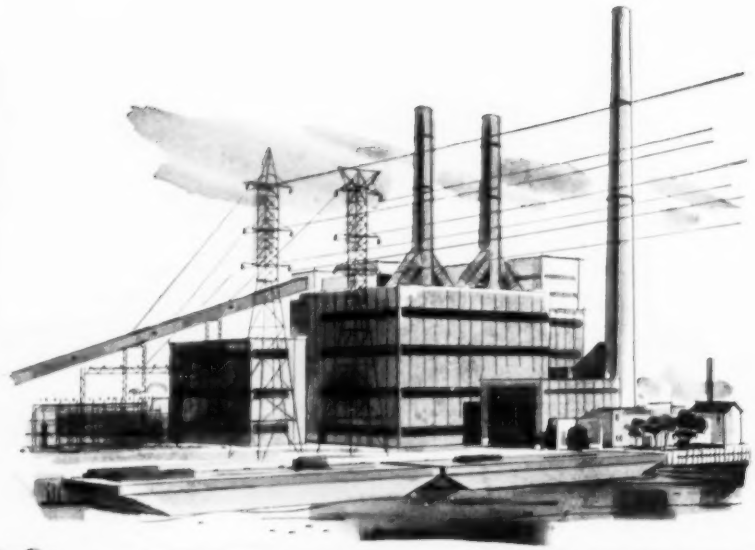
STEEL STACKS



EXPANSION JOINTS

PENSTOCKS, GATES, VALVES – OTHER STEEL FABRICATIONS FOR WATER HANDLING

Above is a partial list of major items. Consult Yuba on related equipment.



LOOK WHAT YUBA MAKES FOR STEAM POWER PLANTS

Electric utilities planning construction of a new steam plant or expansion of present facilities, look to Yuba as a dependable, fully integrated source for all the varied equipment shown here. And for all the skilled services related to its design, engineering, installation or field erection.

Operating nationwide, the divisions and manufacturing plants of Yuba serving the power industry are ideally located to serve you better, providing a single-company responsibility so important in meeting highest product quality standards and delivery requirements – economically.

Your inquiries on any or all of these products or services will receive our prompt and careful attention.

DIVISIONS AND SUBSIDIARIES SERVING THE POWER INDUSTRY: *YUBA HEAT TRANSFER DIVISION, Honesdale, Pa. • ADSCO DIVISION, Buffalo, N.Y. • YUBA MANUFACTURING DIVISION, Benicia, Calif. • SOUTHWEST WELDING & MANUFACTURING DIVISION, Alhambra, Calif. • JUDSON PACIFIC-MURPHY DIVISION, Emeryville, Calif. • YUBA CONSOLIDATED ERECTORS, INC., San Francisco, Calif.*

YUBA

YUBA CONSOLIDATED INDUSTRIES, INC.

351 California St., San Francisco, Calif.

Plants and Sales Offices

NATIONWIDE

Abstracts From the Technical Press—Abroad and Domestic

(Drawn from the Monthly Technical Bulletin, International Combustion, Ltd., London, W. C. 1)

Steam Generation and Power
Mechanical Handling

Rubber-Lined Pipe Trims Maintenance Costs in Ash Handling. L. E. Stewart. *Power*, 1958, **102** (Nov.) 116-17.

Replacement of cast iron by rubber lined steel pipes for the hydraulic transport of fly ash and cinders has prolonged for the life of the pipelines two to ten times and thus proved economic despite the considerably higher capital cost.

Investigation of Specific Heat of Steam Up to 700 atm. abs. and 700° C. M. P. Vukalovich, A. E. Sheindlin and D. S. Rasskazov. *Teploenergetika* 1958, **5** (July) 7-9 (in Russian).

An article by D. S. Rasskazov and A. C. Sheindlin in Teploenergetika No. 11, 1957, gave results of an experimental investigation of the specific heat of steam in the supercritical region of 300-500 atm. abs. The present article analyzes the results in conjunction with the test data obtained, by using the same method and equipment, in regard to the specific heat of steam under pressures of 550-700 atm. abs. and at temperature of 280-700° C.

From *C.E.G.B. Digest* 1958, **10** (Nov. 8) 3037.

Specific Heat of Steam on the Saturation Curve. A. E. Sheindlin, E. E. Shpilrain and V. V. Syschev. *Teploenergetika* 1958, **5** (July) 13-17 (in Russian).

Using thermodynamic equations and experimental data on the caloritic properties of water and steam, the method permits calculation of the specific heat of steam on the saturation curve. The calculation is made in the temperature range 170-370° C and results are compared with experimental data already existing. Sixteen references are appended.

From *C.E.G.B. Digest* 1958, **10** (Nov. 8) 3039.

Investigation into the Correlation of the Rate of Steam Flow of a Drum Type Boiler and the Firing Rate. A. Schneiders. *Energie* 1958, **10** (Oct.) 417-23 (in German).

Measurements were carried out on a natural circulation boiler rated at 250 klb/h at 1300 psi and 985 F supplying, with other boilers, turbines in the power station. The results gave indications of the influence of: (1) Firing rate with and without change of air volume to the mills on rate and amount of increase or decrease of steam volume, dead times and the time required to reach the new steady state; (2) drum pressure; (3) steam exit temperature; (4) action of the spray desuperheater cooling system on steam volume. This latter system has a paramount influence on the increase or decrease of steam volume and makes possible sudden changes of volume of up to 1/3 to 1/2 of the total change.

Analysis of the Steam Turbine Reheat Cycle. J. K. Salisbury. *Trans. A.S.M.E.* 1958, **80** (Nov.) 1629-42.

The analysis is based on a new concept of the reheat cycle, viz: the superposition of a high pressure, high temperature turbine, reheater and feedwater heaters on a low-pressure, high-temperature regenerative cycle system. The gain due to reheat is defined as the fractional decrease in heat rate resulting from adding the reheat portion.

Permissible Rates of Heating and Cooling of Thick Walled Tubes. G. Grass. *Mitt. V.G.B.* No. 56, 1958, (Oct.) 338-40 (in German).

Equations are developed for calculating the permissible rate of temperature change of thick-walled tubes during sudden and gradual heating and cooling. These demonstrate the predominant effect of wall thickness.

Pressure Vessels and the Problem of Brittle Fracture. H. Harris. *Metallurgia*, 1958, **58** (Nov.) 213-17.

Research on this problem and the present state of knowledge are discussed. Although the problem is still not fully understood it is possible to make an appreciation of what can and what should not be done in design, manufacture and use of vessels.

A Preview of Tomorrow's Boilers. E. M. Powell and J. I. Argersinger. *Mech. Engng.* 1958, **80** (Nov.) 72-75.

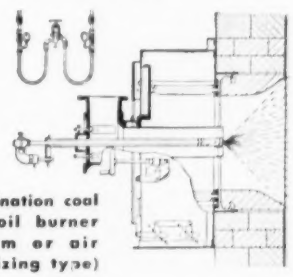
Sub- and supercritical pressures, types of boiler circulation, monotube boilers for sub- and supercritical pressure, boiler controls, variable pressure,

Enco
OIL BURNERS
have these
7 ADVANTAGES
in pulverized coal fired boilers...

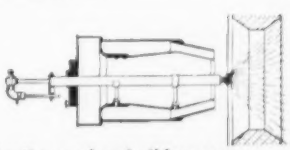
They may be installed in practically all types of pulverized coal burners, with these seven important advantages:

- They warm up cold furnaces
- They ignite pulverized coal—safely
- They assure continuous operation in case coal system fails
- They provide efficient and safe operation on bank and at low loads
- They respond almost instantly to sudden load changes
- They permit operation with oil or coal—whichever is available and lowest in cost per BTU.
- All capacities of steam, air or mechanical-atomizing types are interchangeable

The foregoing are only a few of the reasons why Enco oil-burners have been bought by a long list of leading industrial firms. Details of how Enco oil-burners can be adapted to your present pulverized coal burners will be gladly supplied—without obligation. Write The Engineer Company, 75 West St., New York, N. Y.



Combination coal and oil burner (Steam or air atomizing type)



Combination coal and oil burner (Mechanical atomizing type)

Enco Burners

controlled circulation and typical installations are discussed. It is thought that boilers rated at 3500 klb/h at 3500 psi and a 1050/1050/1050 F and 500 MW turbogenerators will be the next step.

Modern Steam Generator Designs. D. R. Wilson. *Mech. Engng.* 1958, **80** (Nov.) 75–78.

Structural design trends, pulverized coal fired designs, cyclone furnace designs, pressurized furnaces, universal-pressure boiler designs and steam purity are discussed. It is believed that no major changes in design will become apparent in the next 15 to 20 years, but that more boilers will be equipped with cyclone fired and pressurized furnaces operating at supercritical pressure.

Trends in Present Day Boiler Design. D. B. Stewart. *Mech. Engng.* 1958, **80** (Nov.) 78–81.

Natural, forced and dual circulation for large boilers, capacity of boilers, designs with single and twin furnaces, tangent and welded-fin tube walls and combined gas-steam cycles are discussed. A proposed design for a reheat unit rated at 735 klb/h at 1800 psi and 1000/1000 F with natural circulation and twin furnaces with differential firing and heat release rates 3 to 4 times higher than in conventional units would require a space of only 30 × 50 × 100 ft.

Design Requirements for Steam Generation with High Cost Fuels. C. F. Hawley. *Mech. Engng.* 1958, **80** (Nov.) 81–83.

It is thought that major changes in design are unlikely, but that considerable progress can be made by more attention to detail. Designs for multi-fuel firing, furnace and superheater design and arrangements, air preheater design and protection, reduction of auxiliary power requirements by use of pressurized furnaces and automatic control systems are discussed.

Steam Generators for Multiple Fuel Firing. M. O. Funk. *Combustion* 1958, **30** (Oct.) 49–54.

Designs of boilers for the pulp and paper industry able to burn bark, coal, gas and oil in any combination are described. The units range from 55 to 600 klb/h at pressures up to 1300 psi and temperatures up to 1000 F and have combustion controls to take account of the variable supply of bark. Where bark is a high proportion of the total fuel, the fly ash is collected in dust separators and the coarse fraction, generally high in combustibles, is reinjected while the fines are discharged.

Calculation of the Wall Thickness of Superheater Tubes. K. Becker. *Energie* 1958, **10** (Oct.) 411–16 (in German).

A method for the determination of the wall thickness of the tubes of various superheater sections and the selection of the most economical steel is described, which is partly based on calculations and partly on graphs. In this way accurate data are obtained in a fraction of the time required previously.

Fuel Firing

The Selection and Use of Additives in Oil-Fired Boilers. W. D. Jarvis. *J. Inst. Fuel* 1958, **31** (Nov.) 480–91.

Formation of deposits on high and low temperature surfaces of coal and oil fired boilers is discussed and the attempts of reducing deposit formation and corrosion by adding various additives reviewed. Solid additives injected into the combustion chamber frequently cause rapid fouling of the superheater and the deposits can only be removed by off-load cleaning. Ammonia is useful in reducing air heater corrosion, but forms deposits liable to cause clogging and difficult to remove. The results obtained with other additives have not yet been conclusive. Several other possibilities for reducing fouling and corrosion, now under investigation, are discussed.

DEOXY-SOL

SOLUTION OF HYDRAZINE

- Oxygen-
- Scavenger
- for
- Boiler Water
- Treatment

FAIRMOUNT CHEMICAL CO., INC.

136 Liberty St., New York 6, N. Y.

Midwestern Representative:
J. H. DeLamar & Son, Inc.
4529 No. Kedzie Avenue
Chicago 25, Ill.

Ask for pamphlet BW

Does Higher Fuel Efficiency Increase Corrosion? N. Seely. *Corrosion Techn.* 1958, **3** (Nov.) 355–56.

An additive called "Slipco" corrosion controller for fuel oils is described which is a colloidal suspension containing chemically pure calcium hydroxide and zinc oxide stablized with inorganic calcium and other compounds. This additive is easily dispersed in the fuel and thus more active than dolomite or other additives in powder form. The additive forms with vanadium in the oil calcium ortho-vanadate with a m. p. of 2600 F. Being colloidal the additive does not cause abrasion or erosion. The additive not only prevents corrosion by vanadium, but also neutralizes some of the SO_3 formed, due to its content of an inhibitor of sulfuric acid formation, and it promotes the formation of a protective inert layer on internal surfaces. About 1 gal of additive to 20 tons of residual fuel oil is required.

Mineralogical and Physico-Chemical Investigations of Oil Slag. H. Kirsch and W. Pruss. *Mitt. V.G.B.* No. 56, 1958 (Oct.) 329–38 (in German).

The first part presents the results of mineralogical studies of the deposits in oil-fired boilers (furnace, superheater, economizer and air preheater), the second part the corrosive effect of liquid oil slag on refractories, and the third the reactions between V_2O_5 and various additives, especially dolomite and coal ash at temperatures up to 1200 C. It is suggested that combined firing of coal and oil would considerably alleviate deposit formation and slagging difficulties.

Furnaces and Combustion

A Method of Studying the Influence of Flame Characteristics on Heat Transfer in Furnaces. A. M. Godridge, G. G. Thurlow and J. Wallis. *J. Inst. Fuel* 1958, **31** (Nov.) 491–505.

An apparatus is described in which a small flame is burned inside a vertical, cylindrical, insulated combustion chamber of 5-in. diam and results are given of measurements of the heat flow through the furnace walls, temperature, gas analysis and radiation characteristics of the flame. The experiments were carried out with town gas and methane. The interplay of emissivity and temperature, and radiation and convection is discussed.

From *authors' abstract.*

A Study of Heat Exchange Which Takes Place in Vertical Cyclone Combustion Chambers. I. L. Marshak. *Teploenergetika* 1958, **5** (Nov.) 20–25 (in Russian).

Results of investigations into heat exchange in vertical cyclone furnaces when burning different coals are presented. A formula is given for determining the average value of heat flow and the temperature of the gases.

From *author's abstract in English.*

Aerodynamics of Vertical Combustion Chamber with High Degree of Slag Recovery. J. F. Kuvaev. *Teploenergetika* 1958, **5** (Nov.) 25–33 (in Russian).

Aerodynamic peculiarities of the combustion chamber designed by the All-Union Thermal Institute are considered in connection with various burners supplied and for different rates of air supply.

From *author's abstract in English.*

Water-Side Corrosion and Water Treatment

The Effect of Surface Active Agents on the Formation of Boiler Scale. G. H. Ireland. *Corros. Prev. and Contr.* 1958, **5** (Oct.) 57–60.

The mechanism of scale formation is described and the rôle of various agents in forming a mobile sludge discussed. A new surface active agent "Belloid FW" has been discovered which is a neutral salt of an inorganic sulfonic acid, causing particles in the suspension to repel each other and to remain suspended. This salt is non-corrosive, non-volatile, and non-toxic, heat stable and chemically inert and does not cause foaming or priming. Calcium carbonate forms very thin layers of scale if this agent is present, which break away easily and are removed by blow-down or swept out during shutdown. This agent may also be combined with an anti-foaming agent, with hydrazine or with ammonia and neutralizing amines to prevent corrosion. Small quantities of this agent added to river or sewage water will prevent deposit formation.

Complete Demineralisation Plant Circuits. P. Hertwig. *Techn. Überw.* 1958, **10** (Oct.) 363–8 (in German).

Circuits for 2, 3 and 5 bed demineralizers, circular and ring circuits, their special features and field of application are described.

The Properties of Anion Exchangers. Leicher. *Techn. Überw.* 1958, **10** (Oct.) 375–8 (in German).

The composition and activity of anion exchange resins and their functions in feedwater treatment are discussed.

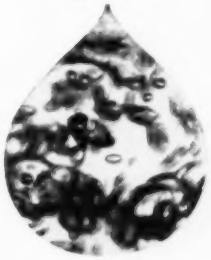
Gas-Side Corrosion and Deposits

High and Low Temperature Corrosions in Boiler Plants. W. Gumz. *Mitt. V.G.B.* No. 56, 1958 (Oct.) 305–19 (in German).

CONCENTROL
PROVIDES
LOW COST, EFFECTIVE CONTROL of FOAM and BOILER WATER CARRY-OVER

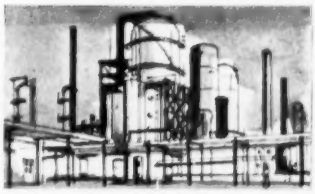
PROVED IN THE LAB:

BEFORE: Foaming of highly alkaline solutions in glass test cylinder.

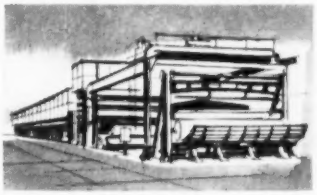


AFTER: Same solution after addition of 12 ppm of Bird-Archer Concentrol antifoam.

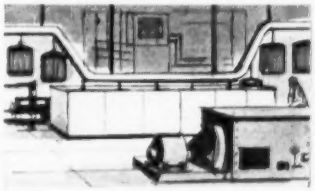
PROVED IN THE FIELD:



Concentrol eliminates foaming, maintains dissolved solids of 10,000 ppm with alkalinity in excess of 2,000 ppm in East Texas refinery.



Concentrol reduces blowdown rate from 15% to 5%, keeps steam quality high in paper mill using highly alkaline makeup water.

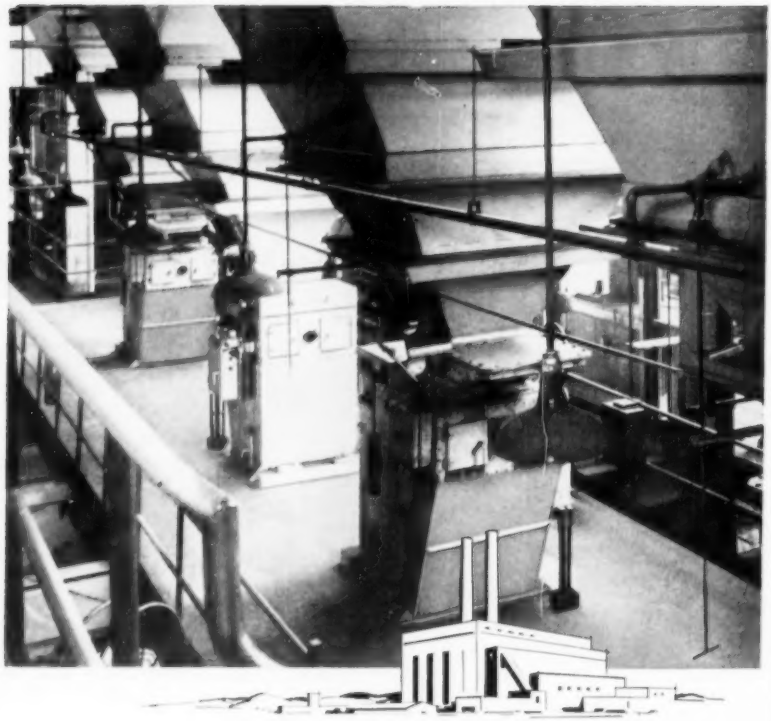


Concentrol eliminates boiler carry-over caused by high alkalinity for an automobile radiator manufacturer using a carbonate water that is Zeolite softened.

Concentrol is available in liquid, powder or briquette forms. Fast acting and resistant to hydrolysis or breakdown under normal boiler temperatures and pressures, it can be fed either continuously or in slugs to boilers. Many plants get the advantages of positive foam control *plus* boiler water sludge conditioning by using Concentrol in combination with organic sludge conditioning agents.

Let a Bird-Archer Water Treatment Engineer prove what Concentrol can do in your plant.
Bird-Archer is always as near as your phone.

BIRD-ARCHER
WATER TREATING CONSULTANTS
The BIRD-ARCHER Company, 4337 N. American St., Phila. 40, Pa.
New York, Chicago
The BIRD-ARCHER CO. of California, 415 Brannan St., San Francisco • Offices in Canada and Mexico



KNOW YOUR FUEL COSTS

...per day...per boiler

with an AUTOMATIC RICHARDSON H-39 COAL SCALE

Coal is money, money that you are burning. And it's vitally important to your balance sheet to know at all times how much of it is going where, how fast.

With an *Automatic Richardson H-39 Coal Scale* you know. It's the superior method of checking boiler and furnace efficiency through records of coal consumption over a set period of time.

A product of the world's foremost manufacturer of automatic weighing and proportioning equipment, the Richardson H-39 –

- records the total weight of all coal consumed and the amount consumed by each boiler.
- has extra large (24" x 24") inlet, prevents coal "arching".
- minimizes condensation with exhaust vents at each end.
- is available in two capacities, 20 and 40 tons per hour.

Write today for Richardson Bulletin 0352A for engineering details and S-58 for complete specifications on the cost saving and budget control features of the H-39 coal scale.

Richardson Scales conform to U. S. Weights and Measures H-44 for your protection

Richardson

MATERIALS HANDLING BY WEIGHT SINCE 1902

RICHARDSON SCALE COMPANY • CLIFTON, NEW JERSEY

Sales and Service Branches in Principal Cities

Also manufactured in Europe to U. S. standards

A broad review of the latest literature on this subject is presented under the main headings of causes of corrosion and prevention of corrosion. In the first part fuel properties and composition, combustion conditions and processes in and beneath the slag layer are discussed. In the second part fuel selection and preparation, improvement of combustion conditions, possibilities of varying the wall temperature, additives, chemical binding of sulfuric acid, neutralization of surfaces, material selection and coatings are discussed.

State of the Mineralogical Investigations into the Causes of Fouling of Heating Surfaces. H. Kirsh, M. T. Mackowsky and I. M. Obelode-Dönhoff. *Mitt. V.G.B.* No. 56, 1958 (Oct.) 320–9 (in German).

The investigations carried out on coal and coal minerals and their behavior at high temperatures and high rates of rise of temperature, on deposits and slags were made by means of light and electron microscopy, X-rays, differential thermoanalysis, chemical studies and lately also by infrared spectrography. The results are set out in diagrams and tables and illustrated by black and white and colored photographs. Fouling is caused mainly by particles in which coal and mineral are intimately mixed and the detailed study of deposits has shown which of the minerals in the coal contribute most to deposit formation. Advice on avoiding or reducing deposit formation cannot be given yet.

Air Pollution from Tall Chimneys. W. Strauss and G. Woodhouse. *Brit. Chem. Engng.* 1958, **3** (Nov.) 620–2.

A series of nomographs is presented to facilitate the estimation of maximum ground-level concentrations of gases or airborne particulate matter, under varying chimney and wind conditions. The nomographs are based on the work of Bosanquet and coworkers, and their use is explained.

Model Checks Collector Design. W. W. Moore and H. Knecht. *Elect. World* 1958, **150** (Nov. 10) 78, 82.

The design of a combined mechanical dust separator and electrostatic precipitator and the connecting ducts for a 2500 klb/h boiler with a flue gas volume of 1,400,000 cu. ft./min. at 300 F has been checked by a $\frac{1}{16}$ size model with tetrachloride gas and threads mounted on probes. The studies revealed the importance of shock losses caused by discontinuities within the boundary of the gas flow; these induce excessive turbulence and increase pressure drop. The collector is to have a removal efficiency of 99 per cent.

Automatic Washing Cuts Air Preheater Cleaning Problems. W. C. Ames. *Power* 1958, **102** (Nov.) 110–11.

At Linden power station the horizontal rotary air preheaters are washed when not in service, by spraying high velocity filtered water (180 F, 200 psi) from both ends into the rotor elements. The time required for washing depends on the state of fouling and is continued until a certain pH is reached in the outflowing water. Washing is done when the pressure drop across the air side has reached a predetermined value.

State of Development and Development Tendencies of Steam-Heated High Pressure Feedwater Preheaters. H. Kerwat. *Mitt. V.G.B.* No. 56, 1958 (Oct.) 358–63 (in German).

Various designs of preheaters are described and some recently developed design details pointed out.

Steam or Air: Which Costs More for Boiler Cleaning? L. B. Schueler. *Power* 1958, **102** (Nov.) 96–7, 198, 200, 202.

The effectiveness and cost of steam and air operated soot blowers are discussed. It is calculated that the relative energy cost for steam is 3.16 times greater than for air. It is also stated that air blowing is more effective because it is done more gradually.

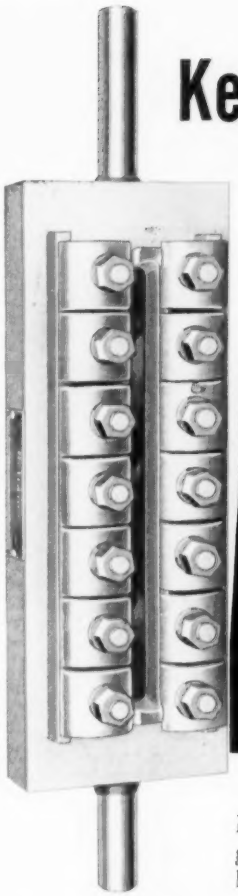
Power Generation and Power Plant

A Look at the Future in Power Station Design. E. H. Kreig. *Mech. Engng.* 1958, **80** (Nov.) 66–70.

The size and equipment of power stations required in 20 and 40 years' time are considered. The size of power stations will probably reach 16,000 MW by 1990 with 1000 MW turbines and boilers which have furnaces with combustion at a pressure of 100 psi. Their availability should be 3 to 4 years. The difficulties of finding suitable sites, ensuring adequate water supply, materials for the high pressure and temperature envisaged, provision of fuel, electric transmission, etc., are discussed. The position of nuclear power generation and other energy sources at present still in the laboratory stage are also considered.

Some Comments on Supercritical Pressure Plants in America. J. R. Finniecome. *Mech. World* 1958, **130** (Nov.) 490–3.

The various American installations operating at supercritical pressure are compared among themselves and with the most modern British units on order for the Blyth "B" station. Calculations are made to show that due to the much higher thermal efficiency of



Keep the "eyes" of your boilers safe

... to protect life and property

Use
Reliance Water Gage Inserts
for leak-tight shatter-proof service

New Reliance Mica-protected Flat Glass Gage Insert for steam pressures to 1500 psi. Rigid wide body; improved Reliance finger-type clamping principle.

Reliance PRISMATIC Gage Insert shows sharp black-white contrast between water and steam. Models for pressures to 350 psi.

It's false economy to "scrimp" on water gages. These vital basic checks on water levels should be of highest quality, assuring continuous clear reading, and safety for workers and equipment . . . A few hints worth considering:

1. See that you have gage inserts on all boilers and supplementary vessels corresponding with the design pressure.
2. Insist on frequent inspections and maintenance to *prevent* trouble.
3. Keep spare inserts and replacement parts on hand for prompt use when needed. (Many plants use spare inserts when necessary to keep gages in continuous service — make repairs when convenient.)

Reliance, oldest manufacturer *specializing* in boiler safety equipment, makes water gage components for all pressures, any visibility range. Also direct-to-drum assemblies. Extra strength — a generous margin of safety — is built into all Reliance products. When you write, please mention your working pressure.

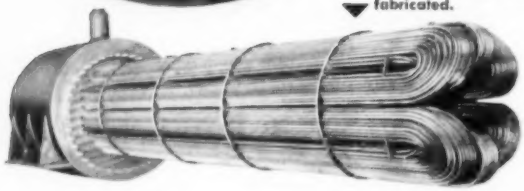
The Reliance Gauge Column Co.
5902 Carnegie Avenue • Cleveland 3, Ohio

BOILER SAFETY DEVICES
Reliance ®

1884 75 YEAR 1959

Highest Standard in Boiler and Pressure Tubing

Every length of Standard Boiler and Pressure Tubing is tested at pressures far beyond code requirements and can be readily bent or otherwise fabricated.



NOW Standard's electric weld boiler tubing is available in much heavier wall thickness than has heretofore been produced. Thus, this extremely uniform tube can be used for still higher pressures.

Wall thicknesses up to .220" minimum wall in 2" outside diameter and smaller can be supplied. This will permit allowable pressures well above 2,500 lbs. for tubes expended into headers or drums or for tubes absorbing heat in water tube units. Larger diameters can be supplied up to .280" minimum wall.

The smooth surface and uniform wall help to reduce thermal stresses and permit better control of rolling tubes into headers or drums.

No where will you find any more modern and complete facilities for precision manufacture and inspection of Boiler and Pressure Tubing than you'll find at Standard.

For complete information on all Standard products and services send for free 8-page folder today.

FREE

8-page folder on all Standard products. Write address below.

STANDARD

THE STANDARD TUBE COMPANY and MICHIGAN STEEL TUBE PRODUCTS DIVISION

24400 Plymouth Road • Detroit 39, Michigan

Welded stainless tubing and pipe • Welded carbon steel mechanical • Boiler and Heat Exchanger Exclusive rigidized patterns • Special Shapes • Steel Tubing—Sizes: ½" OD to 6" OD—.028 to .270 wall Stainless—Sizes: ⅜" OD to 4½"OD—.020 to .187 wall.

these American stations, a considerable saving in capital costs per kw installed and in operating costs is obtained. It is argued that Great Britain cannot afford to neglect the supercritical cycle when ordering new units.

Power Generation in a Binary Power Station. K. Vordermayer. *BWK* 1958, **10** (Nov.) 508–10 (in German).

The advantages of a power station consisting of a high pressure steam topping turbine and a low pressure ammonia vapor turbine are set out. The rich ammonia solution would be evaporated and heated in stages by steam extracted from the high pressure turbine and after passing the low pressure turbine absorbed by a degasified weak solution. The calculations show that a thermal efficiency of 50 per cent could be obtained in such a process which would be particularly interesting for a nuclear power station operating at moderately high temperatures.

Starting Experience with a 150 MW Unit Installation. A. G. Prokopenko, G. E. Krushel and V. A. Kryzhanovsky. COMBUSTION 1958, **30** (Oct.) 38–45.

Russian investigations carried out on a two-boiler 150 MW turbogenerator unit into reducing the starting up time are described. As a result, starting up times from cold were reduced from an average of 39 h to 2½ h, although in this latter case final steam pressure and temperature were reached only after 23 h. The recommended starting procedure is outlined.

Proposed 1500 MW Coal-Fired Power Station at Drakelow. Anon. *Engineer* 1958, **206** (Oct. 31) 699.

The C.E.G.B. have applied for permission to build a 1500 MW Power Station at Drakelow, to be known as "C" station. Drakelow "A" has a capacity of 240 MW and "B" of 480 MW when completed. The size of the units to be installed in "C" station has not yet been determined.

Ideal Site Reduces Plant Costs. E. M. Sommerfield and R. M. Mullen. *Pwr. Engng.* 1958, **62** (Oct.) 95–6.

The Indian River power plant contains two units, each consisting of a pulverized coal-fired boiler rated at 625 klb/h at 1850 psi and 1005/1005 F and a 75 MW turbogenerator. The superheater and reheater tubes are installed and facilitate cleaning. Flue gas recirculation is by damper control. The thermal efficiency is 90%.

The Age of Giants. Anon. *Elect. News and Engng.* 1958, **67** (Sept.) 84–5.

The background development of today's larger generating sets is reviewed

and mention is made of the 300 MW cross-compound machines to be installed in the Lakeview station, Ontario. Steam conditions will be 2300 psi, 1000 F 1000 F. The turbogenerator set will consist of an h.p. and i.p. turbine coupled to a 150 MW generator and will run at 3600 rpm; the other line comprises a second i.p. turbine and two-double flow l.p. turbines coupled to a 150 MW generator and will run at 1800 rpm. The generators are hydrogen-cooled, generating at 13.8 kv, 0.85 p.f. The first set is due to be commissioned in 1961.

From *C.E.G.B. Digest* 1958, **10** (Nov. 22) 3145.

Instruments and Controls

Electronically Operated Power-Station Instrumentation and Control. R. E. Putman. *Trans. Soc. Inst. Techn.* 1958, **10** (Sept.) 106–16.

After reviewing briefly the disadvantages of pneumatic telemetering systems, the paper describes the various types of electrical telemetering devices and electronic controllers available and discusses their application in the industry. The advantages of the electrical medium in the presentation and recording of information fed to control room are summarized and the experiences during the installation of electronic equipment are discussed.

From *C.E.G.B. Digest* 1958, **10** (Nov. 22) 3154.

New Electrical Instruments for Supervision and Control of Operations. C. Frölich. *Energie & Technik* 1958, **10** (Oct.) 309–11 (in German).

The instrument developed by Askania for the measurement and control of pressure, temperature and levels are described. They are characterized by a very low time constant (0.1 sec.) and can be used in various combinations. Dampers and valves are actuated by Ferraris motors.

Data Logging in Power Stations. C. H. Copley and W. A. Corkill. *Elect Times* 1958, **134** (Nov. 20) 771–4.

Data logging equipment can be used to replace recorders, to actuate alarms, and to calculate efficiencies which can be recorded on standard log sheets. A mobile logger could be used to make periodic visits to stations and collect data from specified points. The information can also be put on punched cards or tapes for use in computers.

A Boiler Efficiency Computer. Anon. *Steam Engr.* 1958, **28** (Nov.) 52–3.

N.I.E.E.S. in collaboration with Elliott Bros. Ltd., have designed an analog computer for making calculations of boiler efficiency at a central office from readings transmitted from the boiler plant undergoing tests.

LOWEST PRICE INSURANCE

STANDARDIZE ON SUPER #3000

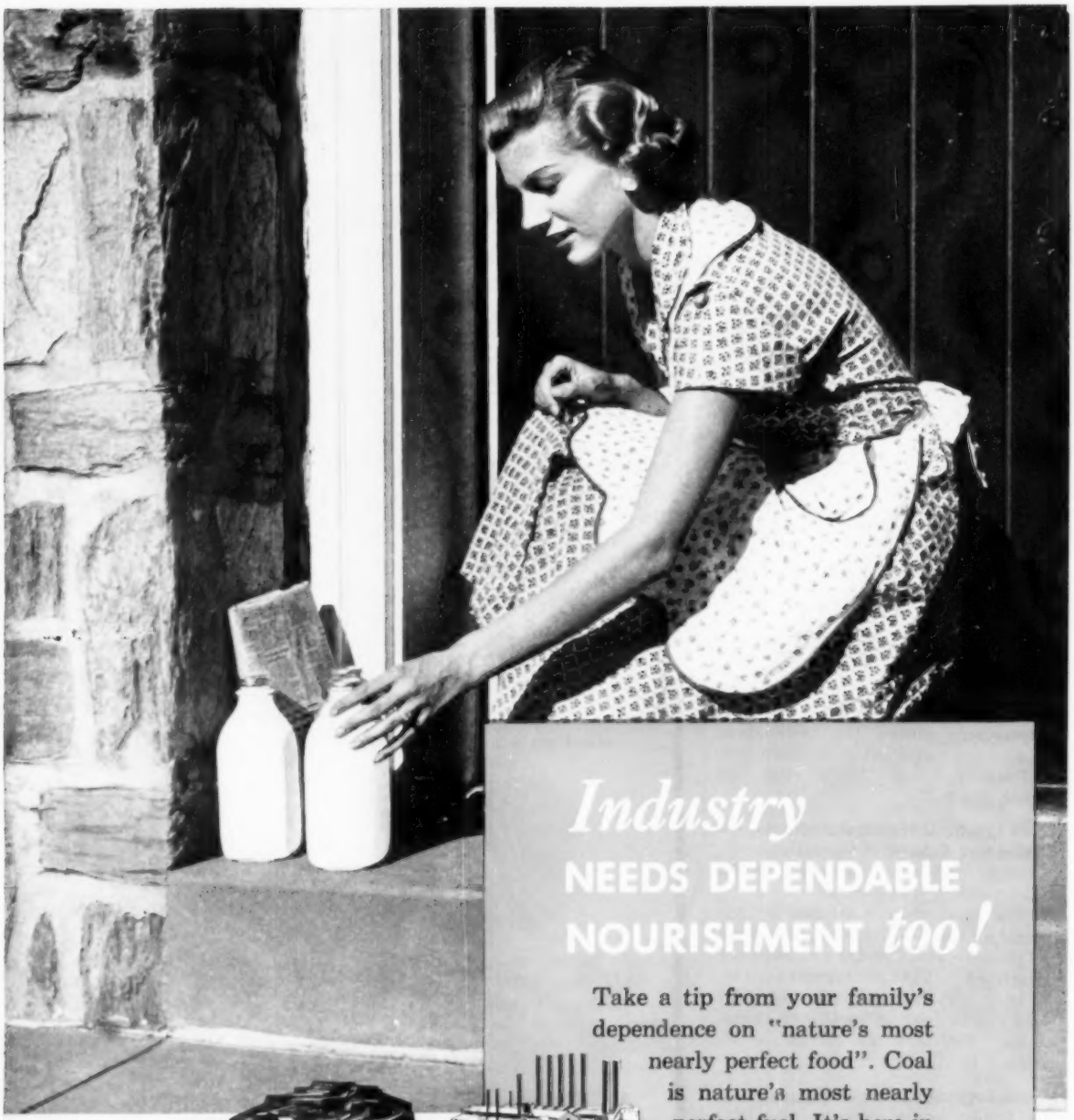
Don't put up with other mortars which may fail if "pushed" too hard. As a general purpose bonding and patching mortar, SUPER #3000 is your *best insurance buy!*

SOUTHERN UTILITY — Reports that all of its plants have standardized on Super #3000—use it wherever a refractory mortar is required. Applications include: repair of baffles; tangential tubes; repair of eroded refractory surfaces; dust collectors.

REFRACTORY & INSULATION CORP.

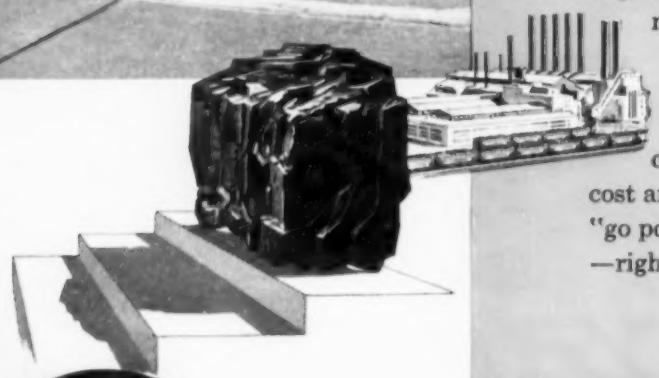
REFRACTORY BONDING AND CASTABLE CEMENTS
INSULATING BLOCK, BLANKETS AND CEMENTS

124 WALL ST. • NEW YORK 5, N. Y.



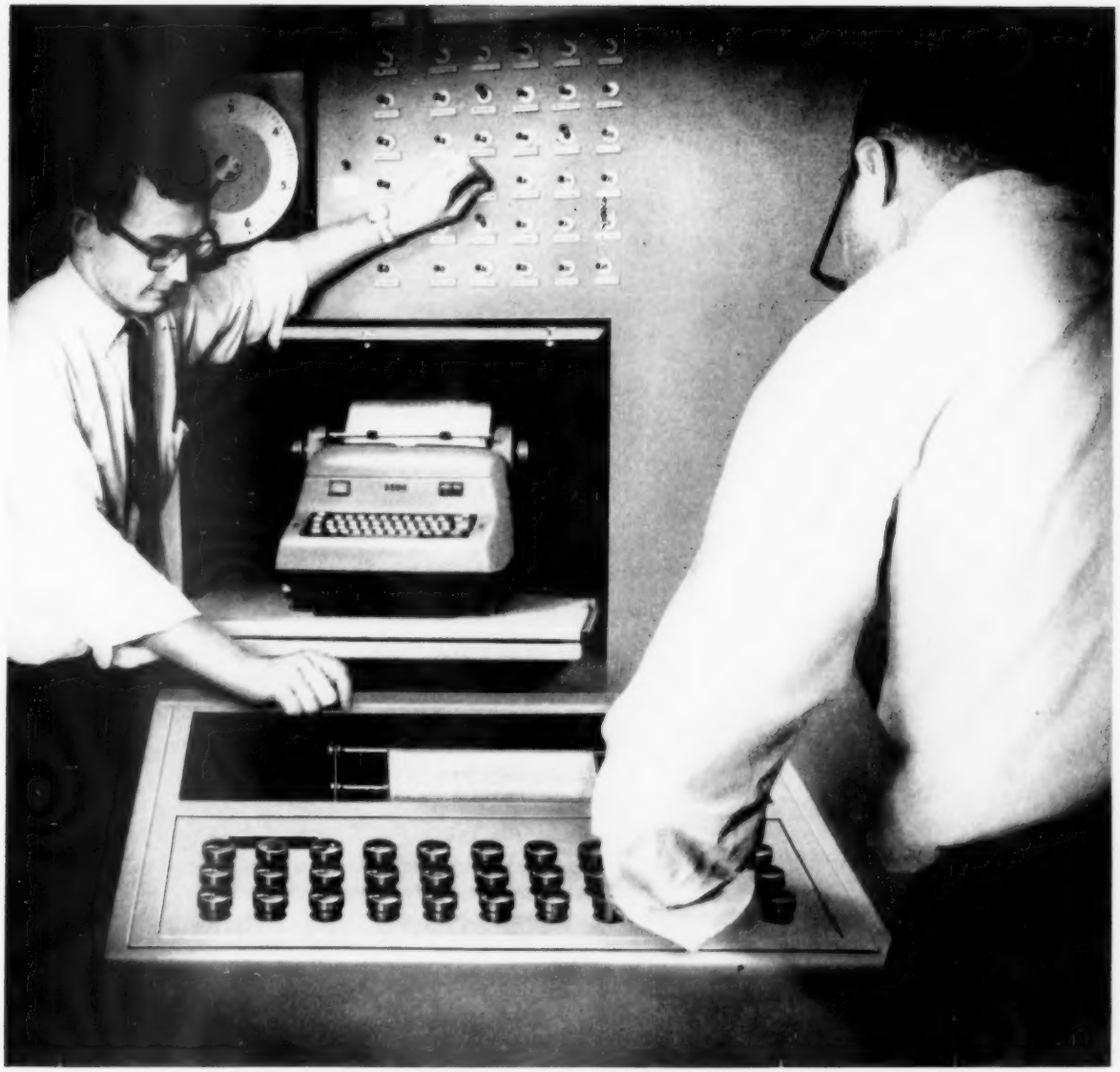
Industry NEEDS DEPENDABLE NOURISHMENT *too!*

Take a tip from your family's dependence on "nature's most nearly perfect food". Coal is nature's most nearly perfect fuel. It's here in abundance for ages to come, a dependably low-cost and most efficient source of "go power"! It's convenient too —right on *Industry's* doorstep.



B&O BITUMINOUS COALS FOR EVERY PURPOSE

Ask our man! BALTIMORE & OHIO RAILROAD, BALTIMORE 1, MD., Phone: LExington 9-0400



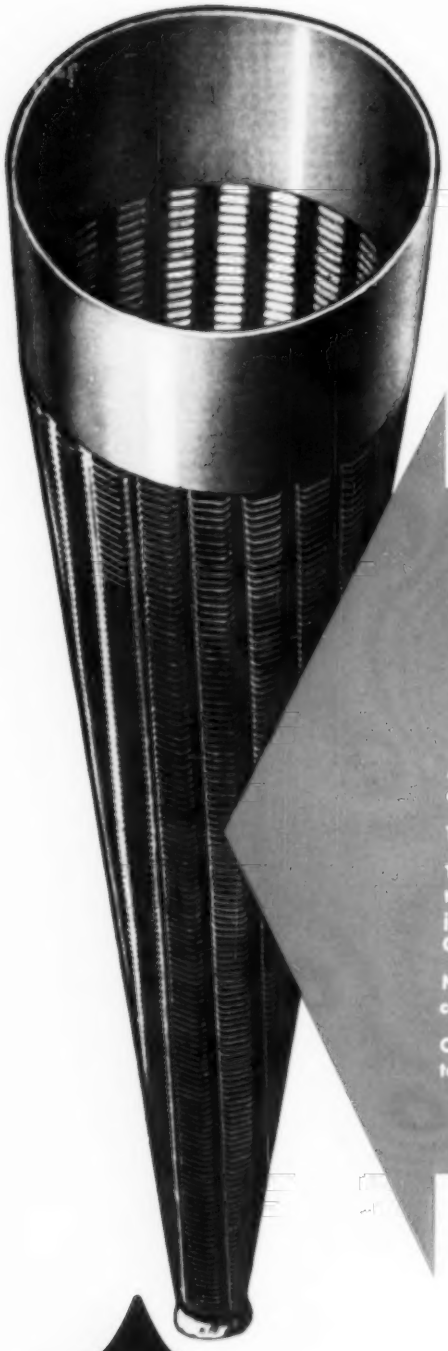
1200 Temperatures entrusted to two L&N data systems!

At the new Bergen Generating Station of Public Service Electric and Gas Company, two 600 point L&N Data Systems will monitor bearing, boiler tube, and condensate temperatures for No. 1 and 2 Units.

Electric typewriters will log data for each unit on continuous 8½" wide log sheets, perforated every 11" . . . one typewriter logging all 600 temperatures while the other is recording off-normals (in red) and up to 10 trends. All inputs are scanned every two minutes for off-normals, with scanning proceeding during logging and trending. As an example of the system's safety measures, all data can go through either typewriter so the operator is never left without vital information.

In designing this system, Public Service and L&N engineers made a thorough study of Bergen's requirements. L&N's contribution was based on 30 years' experience in power plant measurements and an expert knowledge of data processing. For data systems and other power plant controls, call your nearby Field Office or Leeds & Northrup Co., 4972 Stenton Ave., Philadelphia 44, Pa.

Data Systems engineered to power-plant standards by **LEEDS** Instruments **NORTHRUP** Automatic Controls • Furnaces



More than paid for itself in...

20 MONTHS!

A steel mill installed this Green Aerodyne Dust Collector to prevent coal dust wear on the blades of their new turbo-blower.

This turbo-blower ran 24 hours a day, 7 days a week, for 20 months.

Then, for the first time, it was shut down for inspection. They removed the top to inspect blade wear. Did the blower need a reblading job—a job that would cost much more than the total installation costs of the Green Aerodyne Dust Collector?

No. They just re-installed the top and ordered the turbo-blower back into continuous operation and ticketed the next inspection 18 months hence.

Oh yes, when will the Aerodyne Dust Collector wear out? Nobody seems to know. Its life-in-use seems to be practically unlimited.

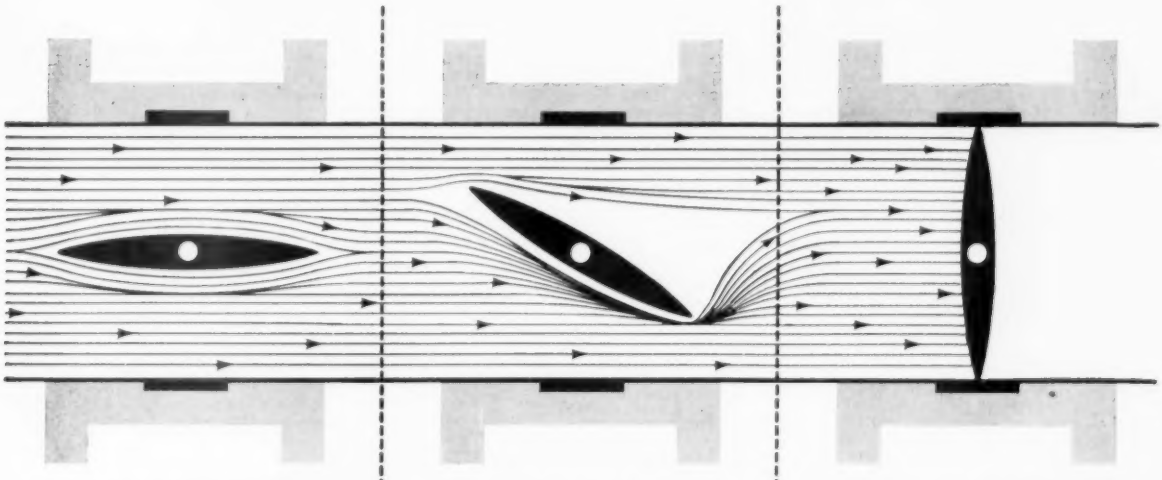
★ ***These Green Aerodyne Dust Collectors really do their jobs. Might save you a considerable sum, too. We'd be happy to show you how.***

Green

THE GREEN FUEL ECONOMIZER CO., INC. BEACON 3, NEW YORK

3 jobs a valve should do

The three functions of a valve are these ...
1...to provide free flow when open,
2...to control flow in intermediate positions,
3...to shut off completely when closed.
Not all valves can do *all* these tasks with equal efficiency, and in many cases, the installation of two valves in series has become an expensive and awkward compromise. Let's see how butterfly valves (as built by Henry Pratt) meet the three vital essentials:



FREE FLOW WHEN OPEN

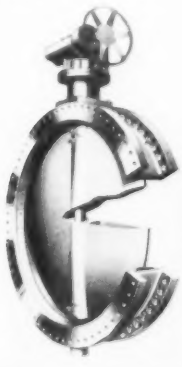
A lens shaped, streamlined valve disc offers the least possible resistance to flow. Actual head loss factor (K) in a fully opened low pressure valve is equal to 0.263, or only 60% of the loss through a 45° pipe elbow.

EFFECTIVE FLOW CONTROL

Flow characteristics of a butterfly valve are similar to those of a V-port plug valve, but with only ⅓ the head loss in the open position. Butterfly valves have a minimum to maximum controllable flow ratio (rangeability) of 25 to 1.

TIGHT CLOSURE

Closing smoothly into the seat, the disc squeezes into the rubber to obtain closure. Heavy rubber seat minimizes wear, assuring **continued** tight shutoff; corrosion resistant disc edge means valve will operate easily even after being closed for years.



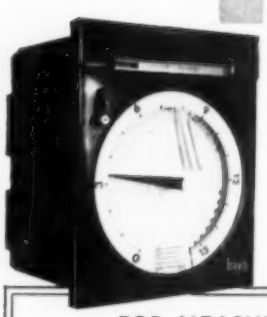
Henry Pratt Low Pressure Rubber Seat Butterfly Valves are suitable for operating temperatures ranging from −20°F. to 190°F., and shutoff pressures ranging from vacuum to 50 psi.

HENRY PRATT RUBBER SEAT Butterfly Valves

If you would like more technical data on butterfly valves, write for the Henry Pratt Manual of Rubber Seat Butterfly Valves, B-2-D.

HENRY PRATT COMPANY, 2222 S. HALSTED ST., CHICAGO 8, ILL. • REPRESENTATIVES IN PRINCIPAL CITIES

NEW



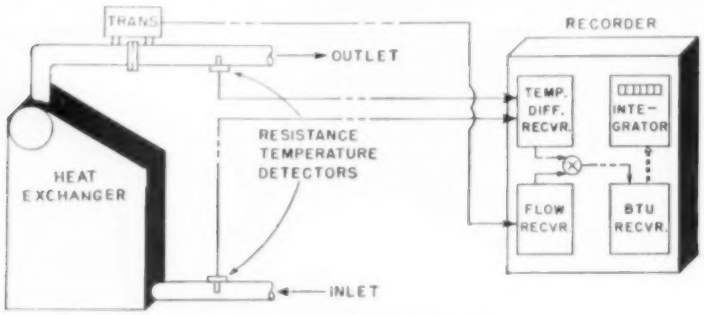
HAYS BTU METER

FOR MEASUREMENT OF HEAT TRANSFER IN

- Hot water boilers
- Refrigerating systems
- Cooling towers
- Chemical processing
- Power applications

Now a single recorder can provide data on BTU, flow, and differential temperature, plus BTU totalization. This new unit incorporates components proven in hundreds of applications. Its operation is indicated in the diagram below.

The temperature of the liquid as it enters the heat exchanger is measured by a platinum resistance temperature element. Another similar element measures liquid temperature leaving the exchanger. A Hays model 245 flow transmitter measures liquid flow through the process. These variables are recorded, retransmitted and multiplied. The product is then transmitted to a BTU receiver which records rate of BTU gain or loss, and to an integrator totalizing BTU's gained or lost.



The features of the new Hays BTU Meter include:

- Only one unit for recording BTU, differential temperature, fluid flow and totalizing BTU
- Increased accuracy. No loss by transmission between recorders.
  Accuracy specifications include:
  Differential temperature: within ± 0.5% chart calibration
  Flow: within ± 0.25 maximum transmitter differential
  BTU Record: slightly over 1% over entire range of Delta T at 70% to 100% of fluid flow
- Easy to install
- Accurate and easy checking of BTU record
- Easy to service. All components readily accessible
- Fast response due to electronic rebalancing of three transmitted signals
- Narrow differential temperature ranges available for maximum accuracy and sensitivity
- Switches can be added for alarm or safety purposes

Model 913 BTU Meters can be adapted to any 20° F minimum to 180° F maximum fluid temperature differential span on operating temperatures of from 32° F to 500° F for the stated accuracies. Greater temperature difference spans can be handled with corresponding change in accuracies. Standard models have been developed for chilled or hot water. Modifications permit use with other fluids.

A new bulletin, 58-B913, contains complete information of the new Hays BTU meter. Write for your copy today.

THE hays CORPORATION

MICHIGAN CITY 1, INDIANA

Advertisers' Index

Air Preheater Corporation, The 23
American-Standard Industrial Division *

Bailey Meter Company 8
Baltimore & Ohio Railroad 56
Bayer Company, The 20
Bird-Archer Company 51
Bituminous Coal Institute *
Buell Engineering Company, Inc. 28
Buffalo Forge Company 5

Cambridge Instrument Company *
Champion Rivet Co., The 61
Clarage Fan Company 62
Cochrane Corporation 22
Combustion Engineering, Inc. Second Cover, 10 and 11
Cooper-Bessemer 14 and 15
Copes-Vulcan Div., Blaw-Knox Company 6 and 7
Crane Company 38

Dampney Company, The 3
De Laval Steam Turbine Company *
Diamond Power Specialty Corporation Third Cover
Dowell *
Dravo Corporation *
E. I. du Pont de Nemours & Co., Grasselli Chemicals Dept. *

Eastern Gas & Fuel Associates *
Edward Valves, Inc. 24 and 25
Engineer Co., The 49

Fairmount Chemical Co. 50
Fly Ash Arrestor Corporation *

Graver Water Conditioning Company *
Green Fuel Economizer Company 58

Hagan Chemicals & Controls, Inc. 2
Hall Laboratories, Div. of Hagan Chemicals & Controls Inc. 9
Haskins-Turner Company *
Hays Corporation, The 60

Ingersoll-Rand Company 13

Johns-Manville *

M. W. Kellogg Company, The 4
Koppers Company, The *

(Continued on page 65)

Ladish Co. ..... *
Leeds & Northrup Company ... 57
Leslie Co. ..... *

Manning, Maxwell & Moore, Inc. ..... *
Maryland Shipbuilding & Drydock Company ..... *
W. K. Mitchell & Company .... *
Morton Salt Company ..... *

National Aluminate Corporation 19

Peabody Engineering Corporation ..... *
Pennsylvania Crusher Div., Bath Iron Works Corp. 12
Pittsburgh Piping & Equipment Company ..... *
Powell Valves 21
Henry Pratt Company 59

Refractory & Insulation Corporation 55
Reliance Gauge Column Company 53
Republic Flow Meters Company ..... *
Republic Steel Corporation ... *
Research-Cottrell, Inc. ..... *
Richardson Scale Company ... 52
Rohm & Haas Company 26

Scovill Manufacturing Company 17
Standard Tube Co., The and Michigan Steel Tube Products Div. 54
Stock Equipment Company ... 18
Sy-Co Corporation ..... *

Todd Shipyards Corp., Products Div. ..... *

Unafrax Construction Co. ..... *

Valley Camp Coal Co. 27

Western Precipitation Corporation ..... Fourth Cover

Westinghouse Electric Corporation ..... *
Worthington Corporation ..... *

Yarnall-Waring Company 16
Yuba Consolidated Industries 48

For Top Quality Welding
On Chrome-Alloy Steels

Use CHAMPION CROLOY® ELECTRODES

For top drawer welding of Chrome Moly Steels, **Champion Croloy Electrodes** have excellent handling characteristics in all positions, and produce radiographically clean welds of unsurpassed mechanical properties. **Champion Croloy Electrodes** are available in all of the popular grades from 1¼% Chrome, ½% Moly to 9% Chrome 1% Moly in 3/32" through 5/16" diameter. Only Croloy Electrodes are identified with the Croloy imprint on each Electrode and are manufactured under U.S. patent license.

Champion also offers a full line of Stainless Steel Electrodes in all analyses with either lime or AC-DC coatings. **Champion** is the leading manufacturer of the increasingly popular 16-8-2 composition, which gives unparalleled freedom from cracking in type 347 and 316 weldments.

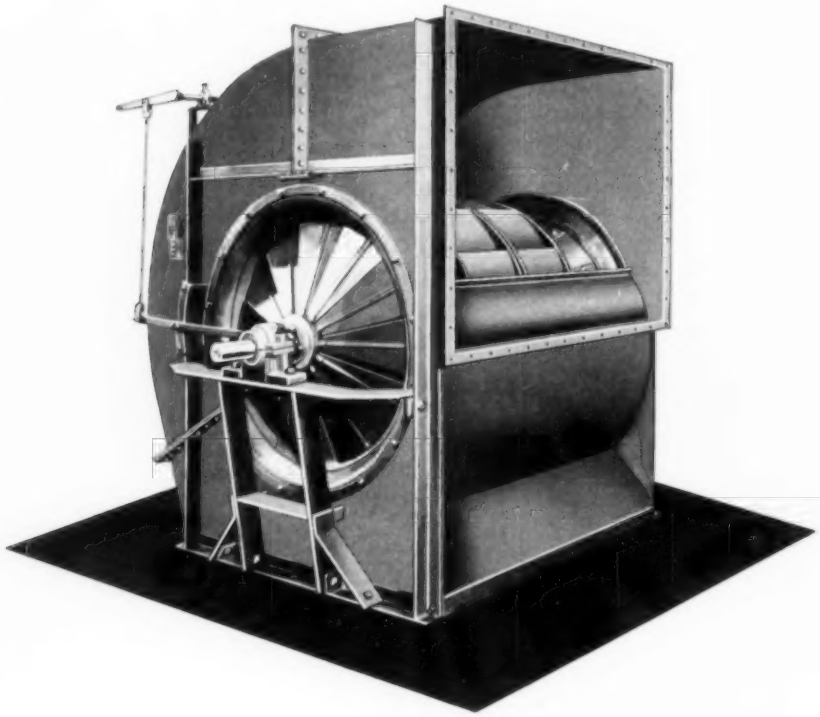
For further information on any of these electrodes, write today.

THE **CHAMPION** RIVET CO.

Cleveland 5, Ohio — East Chicago, Ind.

CLARAGE

Presenting new highs in quietness and dependable broad efficiency...



NEW DYNAFOIL heavy-duty FAN

featuring a perfected airfoil blade design

With this new Clarage Type AF Dynafoil Fan you get stable high efficiency where it counts—under actual operating conditions.

Ideally suited to mechanical draft and heavy-duty applications, such as industrial processes, conduit type air conditioning, and tunnel ventilation, this latest in the Clarage line of superior fan equipment is built in 13 sizes, Classes II, III, and IV construction.

WRITE FOR CATALOG 859 which provides outlined dimensions and description of new Clarage Type AF Dynafoil Fans. Or contact nearest office.

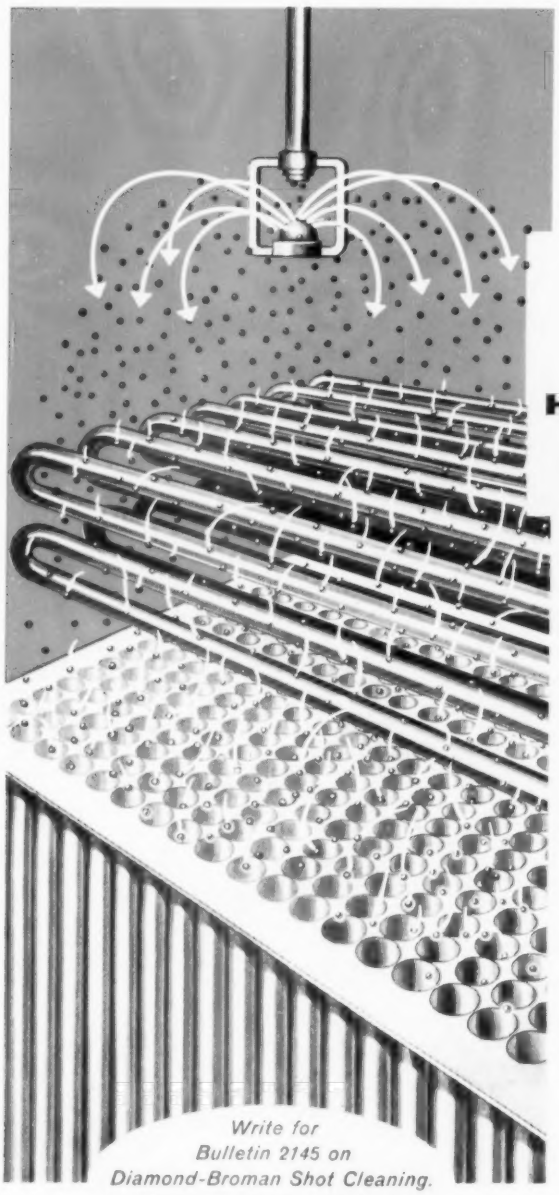
Dependable equipment for making air your servant

CLARAGE FAN COMPANY

Kalamazoo, Michigan

SALES ENGINEERING OFFICES IN ALL PRINCIPAL CITIES • IN CANADA: Canada Fans, Ltd., 4285 Richelieu St., Montreal

Diamond SHOT CLEANING SYSTEM



Write for
Bulletin 2145 on
Diamond-Broman Shot Cleaning.

Diamond gives you better boiler cleaning at lower cost.

. . . Now Ready and Able to

IMPROVE THE CLEANING OF

TUBULAR AIR HEATERS

•

ECONOMIZERS

•

HORIZONTAL SUPERHEATERS

•

REHEATERS

Shot cascading over horizontal tubular surfaces and through vertical air heater tubes, does an excellent job of removing soot and ash deposits from difficult-to-clean surfaces and those which foul rapidly.

Shot Cleaning has proved itself in more than 30 installations in the United States and in more than 800 installations in Europe. Many installations represent exceptionally difficult cleaning problems such as tubular air heaters, economizers and superheaters in black liquor fired boilers in paper mills. In a large central station, the system is now keeping air heaters clean which previously had to be water washed approximately every eight months, each washing requiring a three day boiler outage. With Diamond Shot Cleaning, draft losses are uniformly low and water washing has been eliminated entirely.

Shot is spread by distributors and cascades over tube surfaces ricocheting from tube to tube, or from side to side of internal surfaces of vertical air heater tubes. Much of the ash removed is carried off by flue gas. Heavier particles fall into the shot hopper and recirculate with the shot until broken fine enough to pass out with the gases. Shot accumulated in the hopper is lifted pneumatically to the storage area and reused continuously. Areas which foul rapidly can be kept completely clean by increasing the length of the shot cycle (it can be continuous) without disturbing boiler operation.

Over a period of years Diamond has conducted extensive research in shot cleaning, as a part of our half century policy of providing the best in boiler cleaning. To supplement this program, Diamond acquired U.S. rights to the Broman-Ekstrom system used in Europe.

Diamond

DIAMOND POWER SPECIALTY CORP.

LANCASTER, OHIO

8265

Still ANOTHER Cottrell Advancement By Western Precipitation...

UNIQUE "FULL-RANGE" RAPPER CONTROL PROVIDES ENTIRELY NEW STANDARDS OF VERSATILITY

Rapping Frequency... Rapping Intensity... Rapping Pattern

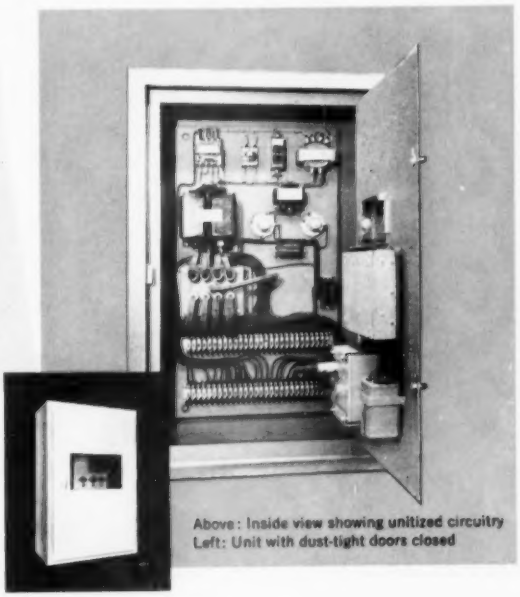
ALL EASILY ADJUSTABLE TO MEET OPERATING REQUIREMENTS

THE PROBLEM:

In the operation of Cottrell Precipitators it is necessary to remove the dust, fume or fly ash that has collected on the plates and cause it to be deposited in a hopper for subsequent removal from the Precipitator. The Rapping System should accomplish this removal with minimum disturbance to the already collected material (to avoid re-entrainment) and with maximum cleaning of the plates.

However, collected materials vary widely in their physical characteristics. Some are sticky. Some agglomerate readily and in thick layers without disrupting electrical operation. Still others have no tendency whatever to agglomerate, but form a sheet of loose particles on the plate.

There is no "typical" dust—no fixed set of conditions to be met. **Yet the Rapper System must be readily adaptable to efficient dust removal, regardless of dust characteristics!**



Above: Inside view showing unitized circuitry
Left: Unit with dust-tight doors closed

THE SOLUTION:

With so many variables to be compensated, unusually wide adjustability of the Rapper System has long been a prime objective for optimum operating efficiency. But complex factors have prevented its attainment until development of Western Precipitation's new "Full Range" Rapper Control.

By simply adjusting a few dials, "Full Range" Control permits:

- **FULL FREQUENCY ADJUSTMENT** from a complete rapping cycle every 50 seconds to one every 3½ hours... or any desired cycle in between!
- **FULL INTENSITY ADJUSTMENT** from zero to maximum over an unusually wide range!
- **FULL PATTERN ADJUSTMENT** 2, 4 or 8 impacts per cycle can be selected, with each cycle varying from light to heavy on successive impacts within the cycle—all automatically controlled to a choice of pre-selected operating limits!

Free! **NEW BROCHURE** which describes and illustrates the new "Full Range" Rapper Control—the latest product of Western Precipitation's program of continuous advancement!

Other Important Advantages...

Greater Safety: The "Full Range" Control has no dangerous high voltage circuits to endanger personnel. Entire unit is in "low-voltage" category.

All "Passive" Design: There are no motors, gears, or other high maintenance components in the "Full Range" Control. It is completely electronic.

Space-Saving Compactness: The "Full Range" Control requires about *half* the space of previous designs. Also is water and dust tight—can be located virtually anywhere.

Unitized Circuitry: All related parts are unitized into separate "cans" for simplified maintenance.

For quick assistance, call or wire **collect** *our nearest office.*

COTTRELL Electrical Precipitators
MULTICLONE Mechanical Collectors
CMP Combination Units
DUALAIRE Jet-Cleaned Filters
THERM-O-FLEX Hi-Temp Filters
TURBULAIRE-DOYLE Scrubbers
HOLO-FLITE Processors
HI-TURBIANT Heaters

WESTERN
PRECIPITATION
CORPORATION

Engineers and Constructors of Equipment for Collection of Suspended Material from Gases ... and Equipment for the Process Industries

LOS ANGELES 54 • NEW YORK 17 • CHICAGO 2 • PITTSBURGH 22 • ATLANTA 5 • SAN FRANCISCO 4

Representatives in all principal cities

Precipitation Company of Canada Ltd., 8285 Mountain Sights Avenue, Montreal 9